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FOOD HABITS OF THE GREAT BASIN DEER HERDS OF CALIFORNIA[1]

HOWARD R. LEACH
Game Management Branch
California Department of Fish and Game

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INTRODUCTION

East of the Sierra Nevada and the Cascade Range lies a section of California considered geographically to be an extension of the Great Basin of the western United States. It is characterized by a sagebrush climax. Inhabiting this area in California are the Rocky Mountain mule deer, *Odocoileus hemionus hemionus* (Rafinesque), and the Inyo mule deer, *Odocoileus hemionus inyoensis* (Cowan) (Figure 1). These deer are largely migratory, summering high in the Sierra Nevada and the Cascade Range and wintering in the foothills and adjacent lower elevations in the Great Basin.

The purpose of this study was to determine the food habits of Rocky Mountain and Inyo mule deer on the Great Basin winter ranges in California, in an effort to contribute to a better understanding

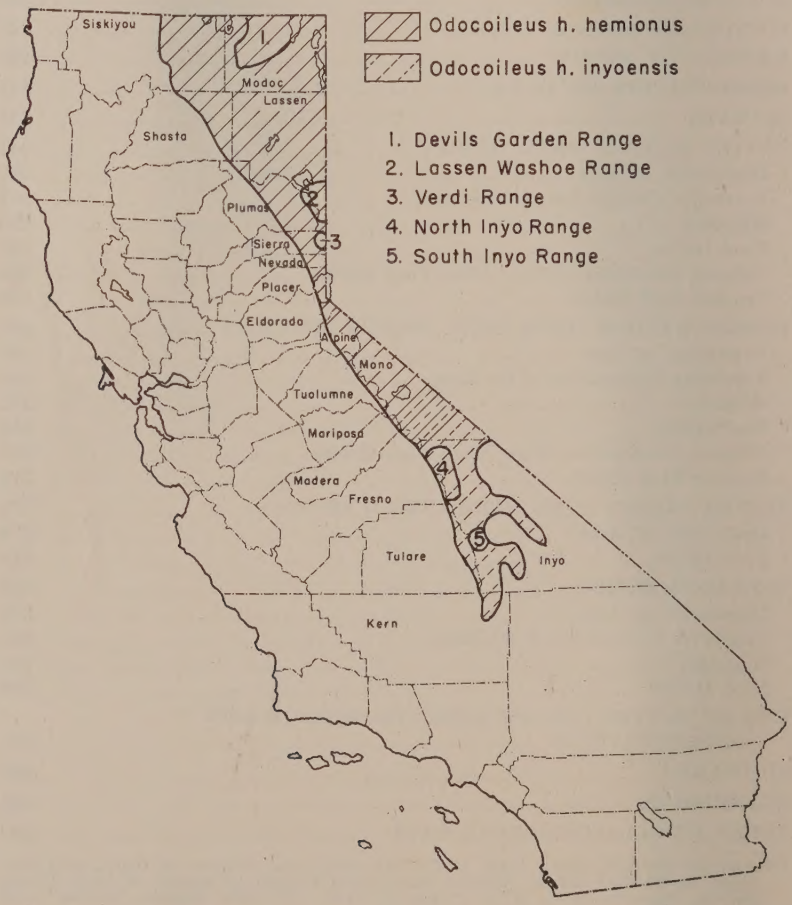

FIGURE 1. Map of the distribution of Rocky Mountain and Inyo mule deer in California, showing the location of the winter ranges of deer herd management units and subunits.

of the ecology of deer with respect to food conditions and climatic phenomena.

ACKNOWLEDGMENTS

The food habits study presented in this paper is but a part of the laboratory and field research conducted by the California Department of Fish and Game in cooperation with the U. S. Forest Service, U. S. Bureau of Land Management, Oregon State Game Commission, and Nevada Fish and Game Commission.

Special acknowledgment is given to Trevenen Wright, James Blaisdell, Robert Lassen, and Fred Jones of the Department of Fish and Game. They cooperated not only in the collection of deer stomach samples, but also were responsible for many of the field data incorporated into the study. The material from the authorized special deer collections was obtained through the fine cooperation of the staff of Department's wildlife disease laboratory, which was given the responsibility of collecting the animals. The author wishes to thank the staff of the Herbarium of the University of California for use of specimens and for assistance in the identification of plant materials. To Cliffa M. Corson is given grateful acknowledgment of the excellent drafting work on the many charts, graphs, and figures used in the report. Carol M. Ferrel contributed substantially to the analyses and assisted in editing the paper.

Free use was made of published and unpublished reports of the Devils Garden Interstate Deer Herd Committee, Lassen-Washoe Interstate Deer Herd Committee, and California Pittman-Robertson Project W-41-R, "Big Game Studies".

HISTORY OF DEER COLLECTIONS

The study of the food habits of California's deer herds by the stomach analysis technique began in 1946, when permission was granted to the disease staff of the California Department (then Division) of Fish and Game to collect 60 female deer from the Interstate Deer Herd in Modoc County. Subsequently, collections of female deer from other herds were authorized by the Fish and Game Commissions of Oregon, Nevada, and California.

The special authorized collections were supplemented by extensive collections of stomach samples and data from deer made available from hunter kills, highway mortality, and winter die-offs.

Table 1 is a history of the sources of the 978 stomach samples reported on in this paper.

METHOD OF STUDY

Stomach samples were obtained in the field by removing a pint or more of material from the rumen. After appropriate labeling, they were preserved in formalin.

The samples were examined with a binocular microscope equipped with a 9x ocular and a 0.7x objective. The material was thoroughly washed through a fine-mesh screen preparatory to examination. After

TABLE 1

Summation of the Field Collection of 978 Deer Stomach Samples

Deer herd	Source of material	Date	Number
Devils Garden	Commission-authorized collection	Monthly collection from November, 1946, to April, 1947	60
	Authorized collection (Oregon Fish and Game Commission)	Monthly collection in Oregon from May to October, 1947	34
	Highway mortality	Winters of 1946-47, 1950-51, and 1951-52	94
	Hunter-killed deer	Special antlerless hunt, November, 1950	40
	Winter die-off	February and March, 1952	99
		Subtotal	327
Lassen-Washoe	Commission-authorized collection	Monthly collection in 1951	50
	Highway mortality	Winters of 1949-50, 1950-51, and 1951-52	278
	Hunter-killed deer	Special antlerless hunt, November, 1951	15
		Subtotal	343
Verdi	Commission-authorized collection	From January to May and from September to December, 1951	30
	Hunter-killed deer	September, 1951	6
		Subtotal	36
Inyo	Commission-authorized collection	From December, 1951, to April, 1952, and from February to April, 1953	121
	Winter die-off	January to April, 1952	151
		Subtotal	272
		Total	978

the items in the sample were identified,[2] a visual estimate of the percentage of each item was made and recorded. No effort was made to separate the plant materials or to measure them individually.

In summarizing the data, the aggregate percentage method, as described by Martin, Gensch, and Brown (1949), was used to determine the volume percentage of food items eaten. The frequency of occurrence expressed in percentage was determined by dividing the number of occurrences of each food item by the total number of samples examined.

[2] Browse species have been identified according to McMinn (1939), and forbs and grasses according to Jepson (1923). The scientific names of the plants not found in the tables have been included in the text.

PRESENTATION OF DATA

Deer management studies in California have been conducted by regions, units, and subunits based on natural deer populations and range boundaries (Longhurst et al., 1952). Certain of these units have been subjected to intensive study. The food habits data represented by the stomach analyses of 978 Great Basin deer have been broken down into the following four management units and subunits: Devils Garden deer herd unit, Doyle subunit of the Lassen-Washoe deer herd unit, Verdi Section of the Loyalton-Truckee subunit of the Sierra Valley deer herd unit, and Inyo deer herd unit.

To interpret fully the dynamics of the deer herds in relation to food habits and range condition it was necessary to present the variable climatic factors affecting both the deer and the range encountered during the course of study. This necessitated the breakdown of the data into monthly and yearly increments for each deer herd, and the discussion is arranged accordingly.

CLIMATE

The climate of the Great Basin is semiarid and characterized by low rainfall, some subzero temperatures in winter, and warm, dry summers. Precipitation is generally limited to a period from September through April. In the northern ranges precipitation normally varies from 8 to 10 inches at the lower elevations to as much as 20 inches in the higher timbered areas. Semidesert conditions exist in the southern Inyo ranges; the precipitation may be no more than 5 inches annually. In the Appendix are included climatological data giving the monthly means of daily maximum and minimum temperatures, the lowest recorded monthly temperatures, precipitation, and snowfall representative of the study areas and of the winter periods concerned.

DEVILS GARDEN DEER HERD

Description of Area

The Devils Garden Interstate deer herd is made up of Rocky Mountain mule deer that summer principally in the Fremont National Forest in Oregon and winter in the Modoc National Forest in California. The summer range covers approximately 406,000 acres and the winter range about 375,000 acres. However, the acreage on which the deer spend the great part of the winter is much smaller, covering approximately 100,000 acres (Interstate Deer Herd Committee, 1947).

Geologically, the Devils Garden area is a portion of the Modoc Plateau. It is of volcanic origin, characterized by an undulating plain with areas of lava overflow and occasional hills rising from 500 to 1,500 feet above the general plateau level. The elevation in California runs from 4,050 feet at Tulelake to over 5,000 feet at Badger Well and Crowder Flat.

Vegetative Composition of the Range

The flora of the region is typically Great Basin sagebrush formation interspersed with other cover type associations (Figures 2, 3, and 4). The higher portions of the range, notably the Crowder Flat and Badger

FIGURE 2. A general view of the ponderosa pine vegetative type characteristic of much of the area inhabited by the Devils Garden deer herd during the early portion of the winter. It is essentially a ponderosa pine-bitterbrush association with open sagebrush flats. *Photograph by the author.*

FIGURE 3. A transition area predominantly of bitterbrush exists between the ponderosa pine type and the lower elevations of the winter range, where juniper is dominant. *Photograph by the author.*

FIGURE 4. The Casuse Mountain area, showing the juniper-annual grass type, characteristic of the lower portions of the winter range. *Photograph by the author.*

Well areas, are characterized by the extension of the ponderosa pine forest type, which supports an understory dominated by bitterbrush. Interspersed are open areas of grassland and flats of sagebrush,[3] with a scattering of Sierra juniper. Associated with the pine forest is the prostrate-growing squaw carpet, an evergreen shrub, thickly matting the ground in some areas. Thickets of mature curlleaf mountain mahogany occur principally on the hill slopes and ridges. Extensive brush fields of greenleaf manzanita and snowbrush fringe the winter range on the slopes of the higher mountains.

An intermediate area, dominated by bitterbrush, exists between the pine forest and the lower portions of the winter range. This bitterbrush association gives way to open flats of sagebrush or grassland interspersed with areas of Sierra juniper. Rubber rabbitbrush and sticky-flowered rabbitbrush occur as subdominants in this plant association. Several species of grasses occur throughout the range; certain areas are dominated by annual cheat grass. The principal perennial grasses present are the blue grasses (*Poa* spp.), squirreltail (*Sitanion* sp.), Idaho fescue (*Festuca idahoensis*), Junegrass (*Koeleria* sp.), needle grasses (*Stipa* spp.), and rye grasses (*Elymus* spp.). Forbs for the most part are frozen out during the first days of frost, but available in the form of dry leafage are balsam root, mule's ear, and Douglas phlox, which are widespread over the area. Tumbling mustard is conspicuous in the disturbed fields in the flats and along the roads.

Table 2 is a summary of the vegetative composition of the Devils Garden area based on 204 line-intercept plots.

[3] In this paper "sagebrush" is considered *Artemisia tridentata*, although several of its subspecies, as presented by Hall and Clements (1923), may be included.

TABLE 2

Percentage Composition of Vegetation of the Devils Garden Winter Range

Grass		
Annual grasses		14.2
Perennial grasses		26.4
Total grass		40.6
Forbs		
Annual forbs		10.4
Perennial forbs		6.9
Total forbs		17.3
Browse		
Arctostaphylos patula	Greenleaf manzanita	0.3
Artemisia tridentata	Sagebrush	21.1
Ceanothus prostratus	Squaw carpet	3.8
Ceanothus velutinus	Snowbrush	Trace
Cercocarpus ledifolius	Curlleaf mountain mahogany	0.3
Chrysothamnus spp.	Rabbitbrush	4.4
Juniperus occidentalis	Sierra juniper	1.3
Pinus sp.	Pine	0.6
Prunus emarginata	Bitter cherry	0.3
Purshia tridentata	Bitterbrush	9.1
Ribes sp.	Gooseberry	Trace
Tetradymia sp.	Horsebrush	Trace
Others		0.9
Total browse		42.1
Percentage of ground covered with available forage		32.0

Migration

The fall migration of deer from Oregon usually occurs in October, with the mass of deer taking well-defined trails into the northeast portion of the winter range. By late November the deer have moved southward from the Crowder Flat and Blue Mountain areas to the Badger Well area and tend to concentrate in this general vicinity during December and January. Movement from this concentration area is determined by climatic conditions. In an open winter the deer distribute themselves over a wide area of the winter range, while heavy storms have a tendency immediately to concentrate the deer in the northwestern portions of the winter range. In very severe winters the deer remain there until the weather permits a return to more favored areas to the south and east. By May the deer move northeastward to the Oregon summer range.

Food Habits

Table 3 is a monthly summary of the food items eaten by 199 Rocky Mountain mule deer on the Devils Garden winter range, expressed in volume percentage and frequency of occurrence in percentage. This is a summary of the food habits of the Interstate deer herd over the three winters of 1946-47, 1950-51, and 1951-52. The graphical presentation of this diet is shown in Figure 5. Not included in this summation of data, but discussed later, are the results of the analyses of the 99 deer stomachs collected from winter-killed deer in 1952.

It is evident from an examination of Table 3 and Figure 5 that there is a definite seasonal trend in deer food habits throughout the winter.

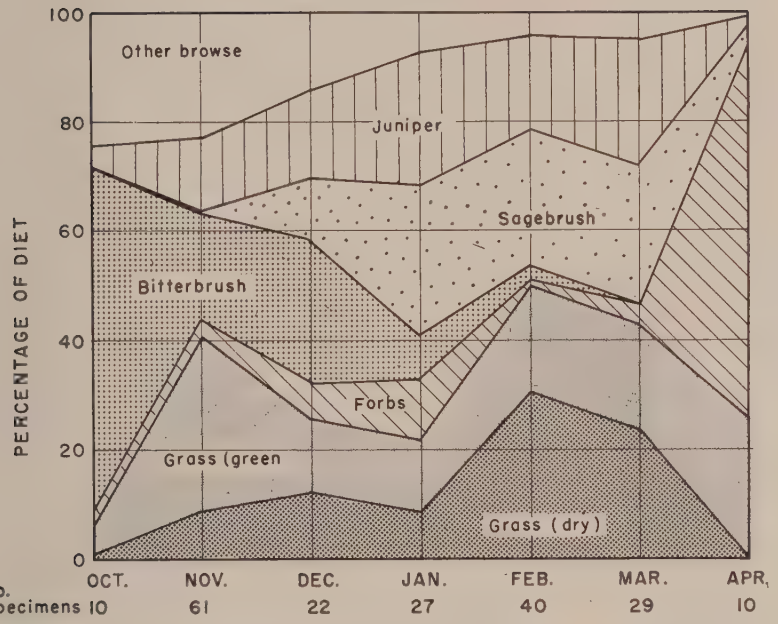

FIGURE 5. Graphic representation of the food habits of the Interstate deer herd in the winters of 1946-47, 1950-51, and 1951-52.

This monthly trend correlates closely with the movement of deer on the wintering area, which is determined by weather conditions and food preferences.

Present at the higher elevations of the winter range and accessible to the deer during the early part of the winter are such browses as curl-leaf mountain mahogany, snowbrush, greenleaf manzanita, and squaw carpet. These plants contribute most heavily to the diet from October through December, and of these plants, squaw carpet is apparently a preferred forage. Deer are known to seek out this plant even when it is covered by snow.

The consumption of bitterbrush exhibits a definite seasonal utilization. As seen in Table 3, bitterbrush made up 59.8 percent by volume of the October diet and was found in 100 percent of the stomachs, but by January and March the consumption of bitterbrush decreased to a point where it contributed little to the diet.

As bitterbrush use falls off in the late winter months, sagebrush takes its place as the staple browse in the diet. There was but one occurrence of sagebrush in the October stomachs and little sagebrush was eaten in November. Beginning in December, the consumption of sagebrush increased appreciably. It made up 12.2 percent of the December diet and was found in 63.6 percent of the stomachs; by January and February it constituted 26.3 and 25.2 percent, respectively, of the diet. This heavy consumption of sagebrush continued in March, but decreased noticeably in April.

TABLE 3

Summary of the Food Items Eaten by 199 Rocky Mountain Mule Deer Collected From the Devils Garden Winter Range, Expressed in Percentages *

Scientific name	Common name		October		November		December		January		February		March		April	
		Number of samples	10		61		22		27		40		29		10	
			Volume	Frequency	Volume	Frequency	Volume	Frequency	Volume	Frequency	Volume	Frequency	Volume	Frequency	Volume	Frequency
Browse																
Pinus ponderosa	Yellow pine		Trace	50.0	Trace	50.8	Trace	31.8	1.5	11.1	Trace	7.5	Trace	3.4	--	--
Libocedrus decurrens	Incense cedar		Trace	20.0	0.6	4.9	--	--	--	--	--	--	--	--	--	--
Juniperus occidentalis	Sierra juniper		4.0	50.0	13.4	93.4	16.2	90.1	24.9	88.9	18.6	87.5	23.1	89.7	1.0	90.0
Arceuthobium campylopodium	Pine mistletoe		Trace	10.0	Trace	1.6	--	--	--	--	--	--	--	--	--	--
Berberis sp.	Barberry		0.6	40.0	--	--	--	--	--	--	--	--	--	--	--	--
Cercocarpus ledifolius	Curlleaf mountain mahogany		11.8	50.0	2.1	31.1	5.0	18.1	Trace	3.7	Trace	2.5	Trace	3.4	Trace	10.0
Purshia tridentata	Bitterbrush		59.8	100.0	19.9	78.7	26.6	77.3	8.2	48.1	3.6	12.5	Trace	17.2	--	--
Prunus demissa	Choke cherry		0.2	10.0	--	--	--	--	--	--	--	--	--	--	--	--
Amelanchier alnifolia	Service berry		-	-	Trace	3.3	Trace	4.5	--	--	--	--	--	--	--	--
Ceanothus prostratus	Squaw carpet		5.5	40.0	16.1	59.0	5.7	36.4	2.8	14.8	1.0	7.5	0.5	10.3	Trace	30.0
Ceanothus velutinus	Snowbrush		8.5	10.0	--	-	--	--	-	--	--	-	--	-	--	--
Arctostaphylos patula	Greenleaf manzanita		0.1	30.0	2.4	37.7	1.6	45.5	0.9	3.7	Trace	5.0	2.2	6.9	0.4	20.0
Chrysothamnus nauseosus	Rubber rabbitbrush		Trace	10.0	Trace	1.6	--	--	2.4	7.4	0.3	10.0	1.4	6.9	--	--
Chrysothamnus viscidiflorus	Rabbitbrush		Trace	10.0	Trace	8.2	-		Trace	14.8	--		--		--	
Artemisia tridentata	Sagebrush		Trace	10.0	0.9	39.3	12.2	63.6	26.3	85.2	25.2	92.5	25.9	86.2	4.0	60.0
	Total browse		90.5		55.4		67.3		67.0		48.7		53.1		5.4	
Forbs																
Fungus	Mushroom		0.5	30.0	Trace	21.1	--	--	--	--	--	--	--	--	--	--
Lichen	Lichen		1.1	20.0	0.5	54.1	0.7	31.8	Trace	18.5	Trace	15.0	0.6	17.2	0.4	10.0
Bryophyta	Club moss		-	-	Trace	1.6	-	--	Trace	3.7	Trace	2.5	Trace	6.9	--	--
Rumex sp.	Dock		Trace	10.0	-	-	--	--	--	--	--	--	-	--	--	--
Eriogonum sp.	Buckwheat		Trace	10.0	Trace	9.8	0.2	18.1	Trace	3.7	Trace	5.0	Trace	3.4	Trace	20.0
Amaranthus sp.	Amaranth		Trace	10.0	Trace	1.6	--	--	--	--	Trace	5.0	--		--	--

Salsola kali	Russian thistle	--	--	--	--	--	--	--	--	Trace	2.5	--	--	--	--
Sisymbrium altissimum	Tumbling mustard	--	--	--	--	-	--	5.9	29.6	0.5	12.5	--	--	-	-
Draba verna	Whitlow grass	--	--	--	--	--	--	--	--	--	--	--	--	Trace	10.0
Platyspermum scapigerum		Trace	10.0	--	--	--	--	--		--	--	-	--	--	--
Erodium cicutarium	Red-stem filaree	--	--	--	--	--	--	-	--	0.3	10.0	--	--	-	-
Fragaria sp.	Wild strawberry	Trace	30.0	--	--	--	--	--	--	--	--	--	--	--	--
Medicago sativa	Alfalfa	--	--	--	--	--	--	--	--	Trace	2.5	--	--	--	--
Phlox douglasii	Phlox	--	--	1.4	13.1	4.8	13.6	0.2	11.1	Trace	2.5	--	--	-	--
Achillea millefolium	Milfoil	--	--	--	--	--	--	Trace	3.7	--	--	--	--	--	--
Balsamorhiza sagittata	Balsam root	--	--	2.1	13.1	0.9	27.3	5.6	18.5	0.5	17.5	Trace	6.9	--	--
Cirsium sp.	Thistle	1.0	10.0	--	--	--	--	Trace	3.7	--	--	--	--	--	--
Compositae	Sunflower family	Trace	10.0	--	--	Trace	9.1	--	--	Trace	2.5	--	--	--	--
Unidentified forbs		0.5	70.0	Trace	26.2	Trace	9.1	Trace	3.7	Trace	7.5	3.1	13.8	68.2	90.0
	Total forbs	3.1		4.0		6.6		11.7		1.3		3.7		68.6	
Grass															
Gramineae (dry)	Grass family	1.8	40.0	9.1	78.7	12.5	63.6	9.2	77.8	33.2	97.5	24.0	65.5	Trace	20.0
Gramineae (green)	Grass family	4.6	100.0	31.5	86.9	13.6	50.0	12.1	51.9	16.8	97.5	19.2	93.1	26.0	30.0
Bromus tectorum (florets)	Cheat grass	--	--	Trace	14.8	--	--	Trace	25.9	Trace	35.0	Trace	37.9	--	--
Triticum aestivum	Cultivated wheat	--	--	--	--	--	--	--	--	Trace	2.5	Trace	3.4	--	--
	Total grass	6.4		40.6		26.1		21.3		50.0		43.2		26.0	

* Includes data from winters of 1946-47, 1950-51, and 1951-52, excluding 99 stomach samples from winter-killed deer in 1952.

Sierra juniper has been considered an emergency deer food on the Interstate deer range by range observers. However, the stomach analyses indicate that juniper is taken all winter long, even when other foods are available. Little juniper appears to be eaten when the deer first arrive on the winter range but, as the season progresses and the deer are forced out of the higher portions of the range, the consumption of juniper increases. In October, it made up 4.0 percent of the diet. By January, February, and March, it contributed 24.9, 18.6, and 23.1 percent of the food, occurring in over 87 percent of the stomachs. The importance of juniper as as emergency food during the critical winters is most evident when its consumption during a mild winter is contrasted with that during a critical one. Such a comparison is made later in the text.

Forbs contribute little to the diet of the deer on the winter range except during April, when the new green growth appears. The dry leafage of balsam root, the stems of tumbling mustard, and phlox appear to contribute most as filler food prior to spring.

The importance of grass to the welfare of the deer on the winter range should not be underestimated. The early October and November rains freshen up the perennial grasses and start the new growth of the annual cheat grass. Deer immediately respond by consuming heavy amounts of green grass, and continue to utilize this food until such

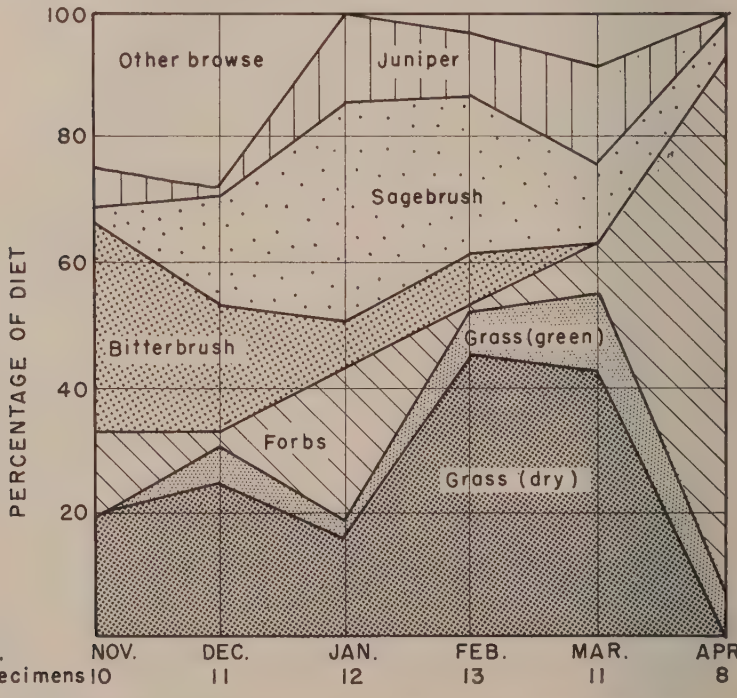

FIGURE 6. Graphic representation of the food habits of the Interstate deer herd in the winter of 1946-47.

time as it is no longer available or until spring, when the grass matures and new leafage appears on the browse species. During winters which are open and mild, deer consume green grass in quantity throughout the winter. Grass, both green and dry, made up only 6.4 percent of the October diet, but contributed 40.6 percent to the November and 26.1, 21.3, 50.0, and 43.2 percent, respectively, to the December, January, February, and March diets.

Climatic Conditions as They Affect Food Habits

Temperature, precipitation, and snowfall are yearly variables which greatly influence the diet and welfare of the deer. During mild winters, loss of deer is negligible and winter survival is reflected in both a high fawn-adult ratio and an increase in numbers of animals migrating into Oregon in the spring. Certainly, maximum carrying capacity is a dynamic factor largely determined by yearly variations in climatic conditions. This weather phenomenon not only directly affects the availability of food, especially the annual herbaceous component of the range, but also exerts physical influence on the deer themselves.

A breakdown of Table 3 into the individual winters represented in the study presents a most interesting picture. Figures 6, 7, and 8 are graphic representations of the winter diet for 1946-47, 1950-51, and 1951-52. Data on the climatic factors of temperature, precipitation, and

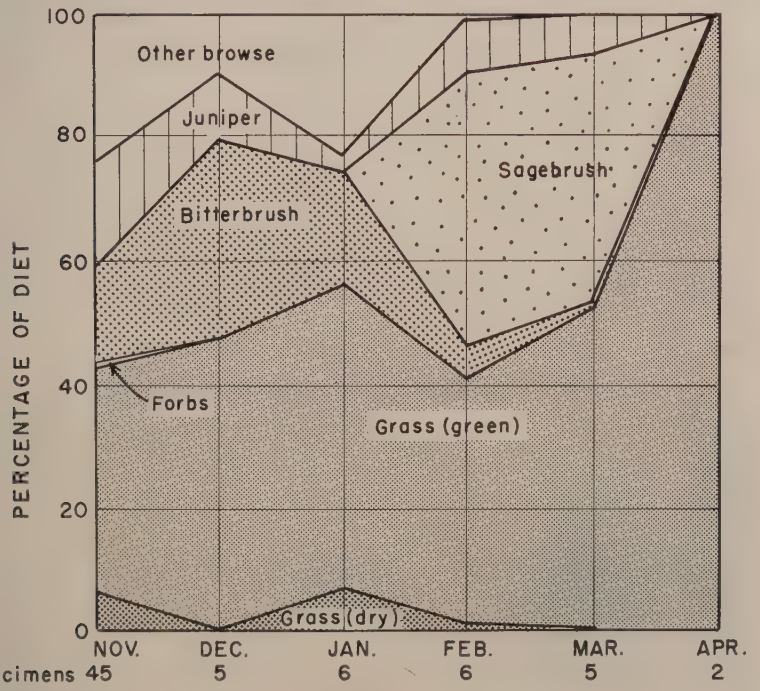

FIGURE 7. Graphic representation of the food habits of the Interstate deer herd in the winter of 1950-51.

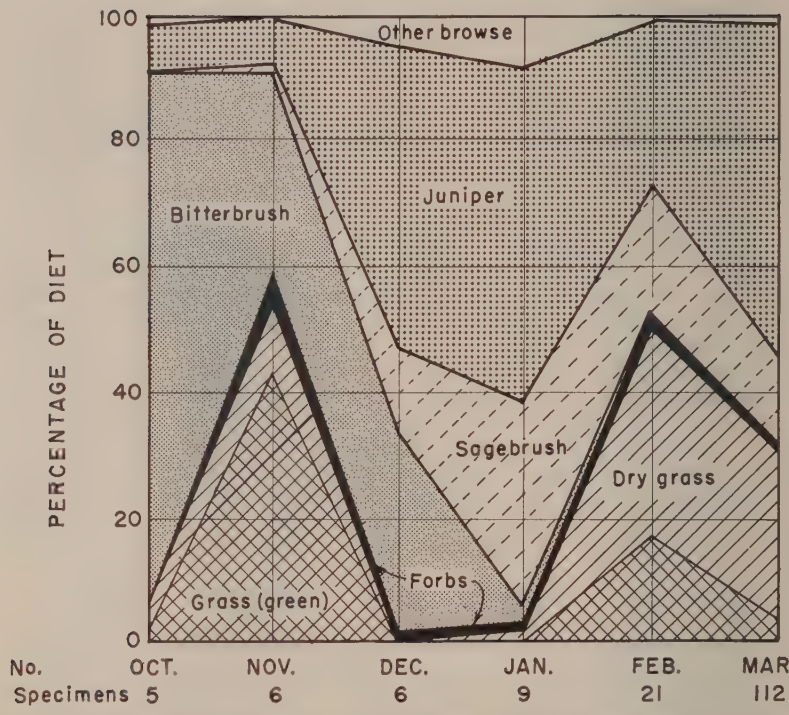

FIGURE 8. Graphic representation of the food habits of the Interstate deer herd in the winter of 1951-52.

snowfall for the years of 1950-51 and 1951-52 are found in Figures A-1, A-2, A-3, and A-4 in the Appendix. These data were obtained from the U. S. Weather Bureau records for Clear Lake Dam, Modoc County. No weather data were available from this station for the winter of 1946-47.

Winter of 1946-47

During the winter of 1946-47, severe temperatures were of short duration and excessive snowfalls did not occur. Except for very short periods, the ground surface was bare of snow all winter (Interstate Deer Herd Committee, 1947). Green grass did not appear on the range, although heavy utilization of dry grass occurred throughout most of the winter. This indicated that the winter was a relatively cold, dry one, inhibiting the growth of grass.

The dry leafage of balsam root, together with the dry stems of tumbling mustard, accounted for the relatively high utilization of forbs in the November and January diets. The consumption of dry grass and dry forb leafage would indicate little or no ground snow at the time. Bitterbrush, although contributing materially to the diet in November, showed a progressive decrease in use over the winter months. The range utilization study for the winter of 1946-47 revealed heavy use of bitterbrush. On 36 sample plots, 82 percent of the bitterbrush was heavily

used, with 60 percent of that use attributed to livestock. The consumption of sagebrush, as shown by stomach analyses, was relatively high from December to March. Little utilization of juniper was apparent. No noticeable winter die-off of deer was reported, with the deer apparently having access to most of the winter range. The absence of green grass on the range may account partly for the reported heavy use of bitterbrush.

Winter of 1950-51

The winter of 1950-51 was considered to be a mild, open one—favorable to deer. The maximum and minimum temperatures were relatively high during most of the winter. Precipitation was heavy in October and December, falling off in the later months of the winter. Snowfall was heavy in January and February, coincident with the lower temperatures, but remained on the ground for brief periods.

It was apparent from the stomach analyses of deer collected during this mild winter that green grass was available every month of the winter and contributed substantially to the diet. Over the entire winter, grass was found to have contributed no less than 40 percent of the bulk of the food in the stomachs of the 69 deer examined. Bitterbrush contributed heavily to the diet from November to January and continued to be utilized in February and March. Sagebrush made up much of the diet in February and March, as the volume of bitterbrush eaten fell off. During this mild, open winter juniper showed a relatively constant utilization, contributing most to the diet in November and December. The open winter evidently permitted the deer to utilize more heavily the browses which otherwise are not available because of ground snow. The other browses, which made up 24.2 percent of the November diet, consisted principally of squaw carpet and greenleaf manzanita. Squaw carpet made up 19.6 percent and greenleaf manzanita 3.2 percent of the November diet, and to a lesser degree both continued to contribute to the diet in December and January.

The result of the range utilization check as reported by the Interstate Deer Herd Committee (1951) showed that the average percentage cropping of bitterbrush by deer was slightly heavier than during previous years, but was more evenly distributed over the range than in the past. The average cropping of juniper by deer was the lightest so far recorded in the study. Significantly, the spring track count revealed a population of 19,570 animals in the Interstate migratory deer herd, compared with the previous winter high of 15,256 and a 1946-47 census of 12,884.

Winter of 1951-52

The winter of 1951-52 was critical. The maximum and minimum temperatures averaged well below those of the winter of 1950-51 for the months from December through April. Rain occurred in the months of October and November but turned to heavy snowfall in December, January, and February. By the first part of January deer began to appear in poor condition and were noticed feeding during the storms. From February 2nd to the 11th the weather was clear and mild and the deer were observed feeding on green grass; however, snow storms again occurred and continued throughout the balance of February.

By the middle of February large numbers of deer carcasses were found, indicating that the peak of the deer die-off occurred at that time. A carcass count on 38,575 acres conducted during the last week of April and the first two days of May resulted in a total count of 2,428 dead deer (Interstate Deer Herd Committee, 1954). It was estimated that approximately 32 percent of the Devils Garden herd succumbed over the winter.

The results of the analyses of 99 deer stomachs collected in March from winter-killed deer were added to the deer stomachs made available through road kills and incorporated into the March data for the winter of 1951-52.

An analysis of Figure 8 reveals that green grass became available on the range in November and received heavy utilization by the deer until the heavy snows in December. During December and January little grass was consumed, but grass was again heavily utilized in February and March. Most of the grass eaten was dry, although a mild spell in the early part of February contributed some green grass to the diet.

Bitterbrush received heavy utilization from November to January, but contributed little or nothing to the diet for the remainder of the winter. This undoubtedly can be attributed in part to the forced movement of deer from the normal winter concentration area in the bitterbrush transition area to the lower juniper-grass association in the Casuse Mountain-Sagehorn area. Sagebrush contributed most heavily to the diet from January through February and to a lesser degree in March.

The utilization of juniper during this critical winter was extremely heavy. Juniper contributed 48.5 percent to the December, 53.6 percent to the January, 25.9 percent to the February, and 52.0 percent to the March diets. Heavy utilization of juniper during critical winters has been revealed by range utilization checks in the past. The winter of 1948-49 was considered to be a critical one; the cropping of juniper for that winter was 22.2 percent, compared with 14.0 percent in 1947-48 and 12.3 percent in 1949-50 (Interstate Deer Herd Committee, 1951). Juniper contributes materially to the diet of the deer in the Devils Garden area during favorable years, but the dependence of the deer on this food during severe winters is very apparent.

During periods of severe weather, deer are forced to move out of the higher elevations of the range and concentrate in its western extremity, in the vicinity of Dry Lake and Casuse Mountain. In 1938-39, when deep snows occurred, it was reported that the area of heaviest concentration of deer was in the Dry Lake-Casuse Mountain area (Fischer et al., 1944). Range fires in 1938, 1941, 1946, and 1950 destroyed much of the browse cover in this area.

The heavy cropping or hedging of juniper in deer concentration areas during such winters is most striking and leads one to believe that they actually exhaust their food supply, although Wright (1952) reported that with the exceptions of two fawns all the deer examined during the die-off period of 1951-52 were found with full stomachs.

Evidence seemingly indicates that deer die-off cannot be attributed entirely to inanition or lack of food, quantitatively speaking. An examination of rumen contents of deer found dead as the result of winter

mortality indicates that they died with full stomachs containing essentially the same food as those of deer surviving the winter. A significant comparison is made later in the text of the food habits of winter-killed deer and deer collected from the same area at the same time by shooting.

Summer Food Habits

Table 4 is a summary of the food items eaten by 29 deer collected during the months of May through September, 1947. The collection was made by personnel of the Oregon State Game Commission of deer from the Interstate deer herd on the summer range in the Fremont National Forest, Lake County, Oregon.

Browse plants made up 54.5 percent of the diet of the deer collected from the summer range. The most important item of food was snowbrush, which made up 28.8 percent of the diet and was found in 62.1 percent of the stomachs. Bitterbrush, although found in 27.6 percent of the stomachs, made up but 6.6 percent of the diet. Other browse plants contributing materially to the summer diet are listed in Table 4. Forbs, which contribute little to the winter diet, proved to be an important item to the deer on the summer range, making up 34.9 percent of the diet. Twenty-four different forbs were identified in the stomachs. Grass, although found in 96.6 percent of the stomachs, contributed but 10.6 percent to the summer diet.

LASSEN-WASHOE DEER HERD (DOYLE SUBUNIT)

Description of Area

The summer range of the Lassen-Washoe deer herd is located principally in the Plumas National Forest in the eastern portion of Plumas County, California. Much of the summer range lies at an elevation of 6,000 feet, with occasional peaks as high as 8,000 feet. The winter range extends along the eastern slope of the Sierra Nevada from the vicinity of Milford south to Peavine and eastward into Washoe County, Nevada (Figure 1). The winter range of the Lassen-Washoe deer herd embraces about 228,400 acres of public and private land, whereas the summer range encompasses some 330,000 acres, made up mostly of national forest lands.

Vegetative Composition of the Range

The summer range is of a forest type dominated by ponderosa pine, jeffrey pine, and white fir. Some juniper is present. Aspen and mountain alder (*Alnus tenuifolia*) grow along the streams and on the slopes bordering the many meadows and small valleys. As the result of fire and logging, extensive brush fields of greenleaf manzanita and snowbrush occur throughout much of the summer range. Other less prevalent browses are service berry, choke cherry, and snowberry. The sagebrush formation extends into the lower portion of the summer range and is interspersed throughout the timbered areas. Sagebrush and bitterbrush constitute the principal understory, with squaw carpet contributing to the ground cover. Many of the canyon slopes bordering the eastern crest of the summer range are wooded with California black oak, with occasional dense thickets of mature curlleaf mountain mahogany. The principal perennial grasses are Idaho fescue, squirreltail,

needlegrass, Sandberg bluegrass (*Poa secunda*), and bluebunch wheat grass (*Agropyron spicatum*). Cheat grass is prevalent on the lower reaches of the summer range.

TABLE 4

Summary of the Food Items Eaten by 29 Rocky Mountain Mule Deer Collected From the Summer Range of the Interstate Deer Herd, Lake County, Oregon, Expressed in Percentages *

Scientific name	Common name	Volume	Frequency
Browse			
Ceanothus velutinus	Snowbrush	28.8	62.1
Purshia tridentata	Bitterbursh	6.6	27.6
Prunus emarginata	Bitter cherry	4.3	24.1
Cercocarpus ledifolius	Curlleaf mountain mahogany	3.5	27.6
Pachystima myrsinites	Oregon boxwood	2.2	6.9
Prunus demissa	Choke cherry	2.1	17.2
Berberis sp.	Barberry	2.1	27.6
Amelanchier alnifolia	Service berry	1.8	37.9
Arctostaphylos sp.	Manzanita	1.7	24.1
Ceanothus prostratus	Squaw carpet	1.4	27.6
Pinus ponderosa	Yellow pine	Trace	58.6
Abies concolor	White fir	Trace	17.2
Librocedrus decurrens	Incense cedar	Trace	17.2
Populus tremuloides	Aspen	Trace	3.4
Arctostaphylos patula	Greenleaf manzanita	Trace	3.4
Symphoricarpos sp.	Snowberry	Trace	6.9
Artemisia tridentata	Sagebrush	Trace	3.4
Unidentified browse		Trace	3.4
	Total browse	54.5	
Forbs			
Fragaria sp.	Wild strawberry	3.7	55.2
Lichen	Lichen	2.4	31.0
Balsamorhiza sp.	Balsam root	1.7	6.9
Lomatium sp.	Hog fennel	1.6	13.7
Liliaceae	Lily family	1.0	6.9
Cordylanthus sp.	Bird's beak	0.9	10.3
Eriogonum sp.	Wild buckwheat	0.5	3.4
Fungus	Mushroom	0.3	24.1
Ranunculus sp.	Buttercup	0.2	27.6
Allium sp.	Wild onion	Trace	6.9
Polygonum sp.	Knotweed	Trace	44.8
Cruciferae	Mustard family	Trace	3.4
Rosaceae	Rose family	Trace	3.4
Thermopsis gracilis	False lupine	Trace	6.9
Leguminosae	Pea family	Trace	10.3
Trifolium sp.	Clover	Trace	17.2
Epilobium sp.	Willow herd	Trace	3.4
Umbelliferae	Parsley family	Trace	3.4
Polemoniaceae	Gilia family	Trace	3.4
Phlox sp.	Phlox	Trace	3.4
Hesperochiron sp.	Hesperochiron	Trace	3.4
Boraginaceae	Borage family	Trace	3.4
Viola sp.	Violet	Trace	3.4
Collinsia sp.	Collinsia	Trace	6.9
Compositae	Sunflower family	Trace	10.3
Taraxacum sp.	Dandelion	Trace	3.4
Unidentified forbs		22.6	93.1
	Total forbs	34.9	
Grass and grass-like plants			
Gramineae (green)	Grass family	10.6	96.6
Carex sp.	Sedge	Trace	10.3
	Total grass	10.6	

* The number of deer collected in 1947 by months were: May, 5; June, 5; July, 5; August, 8; and September, 6.

Sagebrush dominates the winter range, with an interspersal of bitterbrush, desert peach, California wildrose, juniper, mormon tea, horsebrush (*Tetradymia canescens*), spiny hop sage (*Grayia spinosa*), shadscale (*Atriplex confertifolia*), and gooseberry (Figure 9). Rubber rabbitbrush and sticky-flowered rabbitbrush also occur on the range. In areas influenced by fire or agricultural disturbances, rabbitbrush, desert peach, and/or cheat grass comprise the resulting plant succession. Willow and creek dogwood (*Cornus stolonifera* var. *californica*) are found along the intermittent streams flowing into the valley. Very few perennial grasses occur; those present are principally Idaho fescue, Indian rice (*Oryzopsis hymenoides*), Sandberg bluegrass, needlegrass, wheat grass, squirreltail, salt grass, and rye grass. The dominant grass types are annuals, notably cheat grass. Along the foot of the mountains on the west side of Honey Lake Basin and Long Valley, ranches are found wherever water is available for the irrigation of hay land. Alfalfa and meadow hay are grown for the winter feeding of livestock. Ranches are less numerous at the southern and eastern extremity of the winter range.

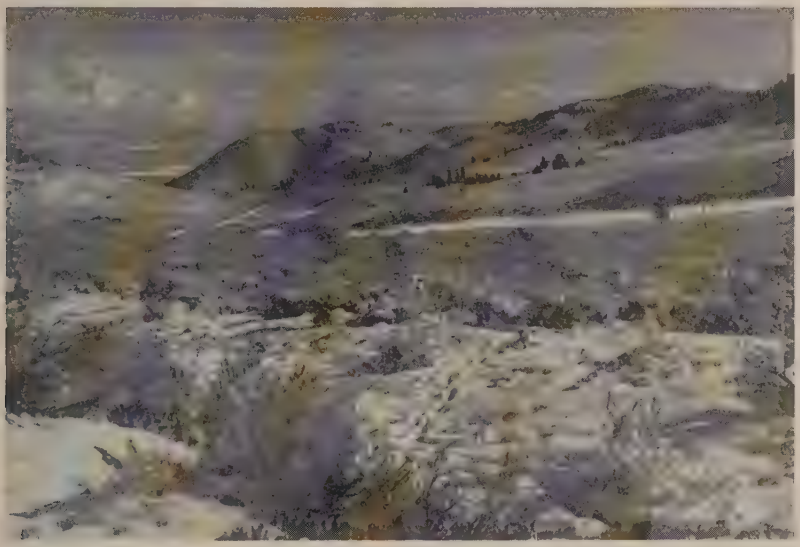

FIGURE 9. A view of the upper edge of the Lassen-Washoe winter range near Doyle, looking eastward towards Nevada. *Photograph by H. D. Bissell, December, 1955.*

The vegetative composition of the Lassen-Washoe deer range based on 243 line-point plots is given in Table 5.

Although the plant associations found on the Lassen-Washoe winter range are similar to those found on the Devils Garden, the vegetative composition of the two winter ranges differs considerably more than is shown by comparing the forage composition surveys (Tables 2 and 5). These surveys are essentially attempts to determine an average sampling of the various vegetative types on designated key concentration

TABLE 5

Percentage Composition of Vegetation on the Lassen-Washoe Winter Range

Grass		
Annual grasses		31.2
Perennial grasses		1.5
Total grass		32.7
Forbs		
Annual forbs		3.1
Perennial forbs		0.6
Total forbs		3.7
Browse		
Artemisia tridentata	Sagebrush	38.0
Ceanothus prostratus	Squaw carpet	Trace
Cercocarpus ledifolius	Curlleaf mountain mahogany	Trace
Chrysothamnus spp.	Rabbitbrush	4.6
Ephedra sp.	Mormon tea	0.3
Grayia spinosa	Hop sage	0.3
Juniperus occidentalis	Sierra juniper	1.3
Populus tremuloides	Aspen	0.3
Prunus andersonii	Desert peach	4.4
Purshia tridentata	Bitterbrush	8.5
Ribes sp.	Gooseberry	0.9
Salix sp.	Willow	Trace
Tetradymia sp.	Horsebrush	3.4
Others		1.1
Total browse		63.6
Percentage of ground covered with available forage		32.0

areas on the winter deer range. The Devils Garden area is characterized by a variety of vegetative types, while the Lassen-Washoe winter range is largely an homogenous sagebrush-annual grass cover type. Significantly, the Lassen-Washoe winter range represents a more arid and decadent range, as well as one of a more dominant sagebrush climax than that of the Devils Garden.

Migration

The migration of deer from the summer range to the winter range occurs usually in late October or early November. The altitudinal movement of deer is accomplished in a short period of time, due to the abruptness of the eastern slope of the Sierra Nevada, which permits rapid transition from summer to winter range. However, the migration is often delayed in open, mild winters, when the deer tend to linger about the lower edge of the summer range until snow forces them to lower elevations. Normally, the majority of the deer herd is found to concentrate about the better bitterbrush area, which is a belt extending generally along the base of the mountains. A sizeable portion of the herd is known to pass into the Fort Sage Mountain and Red Rock areas, thence eastward into Nevada.

Food Habits

A monthly summary of the principal food items eaten by 327 mule deer, expressed in volume percentage and frequency of occurrence in percentage, is shown in Table 6. Table 7 is a supplementary list of the

TABLE 6

Food Items Eaten by 327 Rocky Mountain Mule Deer Collected from the Lassen-Washoe Winter Range, Expressed in Percentages *

Scientific name	Common name	Number of specimens	September 6		October 27		November 32		December 30		January 17		February 51		March 87		April 70		May 7	
			Volume	Frequency	Volume	Frequency	Volume	Frequency	Volume	Frequency	Volume	Frequency	Volume	Frequency	Volume	Frequency	Volume	Frequency	Volume	Frequency
Browse																				
Juniperus occidentalis	Sierra juniper		--	--	--	--	Trace	3.1	1.2	16.7	Trace	5.8	0.8	13.7	0.5	17.2	0.3	10.0	--	--
Pinus ponderosa	Yellow pine		--	--	Trace	7.4	Trace	12.5	Trace	33.3	0.7	23.5	4.6	21.6	1.1	23.0	1.7	37.1	--	--
Abies concolor	White fir		--	--	--	--	--	--	Trace	6.7	1.1	5.8	Trace	3.9	0.5	4.6	Trace	1.4	--	--
Salix sp.	Willow		--	--	1.1	22.2	6.4	21.9	Trace	3.3	Trace	5.8	0.9	7.8	Trace	14.9	Trace	7.1	--	--
Quercus kelloggii	California black oak		6.2	50.0	8.0	33.3	2.6	15.6	Trace	16.7	0.3	11.8	0.3	31.3	0.3	23.0	Trace	24.3	--	--
Cercocarpus ledifolius	Curlleaf mountain mahogany		10.5	16.7	0.9	22.2	0.7	18.8	5.0	30.0	1.6	11.8	0.1	7.8	Trace	4.6	0.3	7.1	--	--
Prunus andersonii	Desert peach		--	--	Trace	3.7	1.5	25.0	--	--	--	--	Trace	5.9	Trace	3.4	9.2	22.9	23.9	57.1
Prunus demissa	Choke cherry		3.3	33.3	2.2	14.8	--	--	--	--	--	--	--	--	2.3	21.8	Trace	1.4	--	--
Purshia tridentata	Bitterbrush		60.2	100.0	62.3	85.2	51.6	87.5	20.5	63.3	10.0	58.8	9.9	45.1	--	--	4.8	34.3	14.7	57.1
Rosa californica	California wild rose		5.5	33.3	6.7	18.5	Trace	9.3	--	--	--	--	Trace	1.9	--	--	2.1	4.3	Trace	28.6
Ceanothus prostratus	Squaw carpet		5.8	33.3	0.2	18.5	0.8	9.3	3.9	33.3	--	--	1.1	5.9	0.6	3.4	2.0	20.0	0.3	14.3
Ceanothus velutinus	Snowbrush		Trace	16.7	1.5	18.5	3.6	25.0	2.6	20.0	0.3	17.6	0.2	3.9	0.2	1.1	2.5	8.5	--	--
Artemisia tridentata	Sagebrush		--	--	3.5	51.9	11.8	87.5	26.9	90.0	64.9	94.1	53.4	98.0	54.5	100.0	34.4	88.5	44.4	100.0
Chrysothamnus viscidiflorus	Rabbitbrush		--	--	Trace	14.8	Trace	18.7	1.3	13.3	Trace	5.8	Trace	1.9	Trace	1.1	Trace	7.1	--	--
Miscellaneous and unidentified browse			1.0	--	Trace	--	0.7	--	1.7	--	0.3	--	1.0	--	0.9	--	0.3	--	Trace	--
	Total browse		92.5		86.4		79.7		63.1		79.2		72.3		60.9		57.6		83.3	
Forbs																				
Medicago sativa	Alfalfa		--	--	1.3	14.8	0.5	9.3	1.9	6.7	Trace	5.8	3.3	17.6	6.8	21.8	6.9	27.1	--	--
Melilotus spp.	Sweet clover		7.5	50.0	6.1	14.8	Trace	3.1	--	--	--	--	--	--	--	--	--	--	--	--
Lomatium sp.	Hog fennel		--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.2	5.7	5.7	14.3
Phlox sp.	Phlox		--	--	--	--	1.7	3.1	Trace	3.3	--	--	--	--	0.9	1.1	Trace	2.9	Trace	14.3
Balsamorhiza sagittata	Balsam root		--	--	Trace	3.7	1.3	15.6	4.5	16.7	--	--	Trace	1.9	--	--	--	--	--	--
Wyethia mollis	Mule-ears		--	--	Trace	14.8	Trace	3.1	1.2	13.3	Trace	5.8	Trace	3.9	--	--	--	--	--	--
Miscellaneous and unidentified forbs			Trace	--	5.2	--	2.4	--	1.1	--	0.6	--	3.5	--	1.1	--	0.9	--	1.8	--
	Total forbs		7.5		12.6		5.9		8.7		0.6		6.8		8.8		8.0		7.5	
Grass																				
Gramineae (dry)	Grass family		Trace	66.6	Trace	25.9	8.1	75.0	6.3	80.0	16.6	88.2	7.7	78.4	13.1	88.5	7.5	64.3	Trace	28.6
Gramineae (green)	Grass family		Trace	50.0	1.0	63.0	6.3	62.5	21.9	66.7	3.6	88.2	13.1	76.5	17.1	90.8	26.5	94.3	9.2	100.0
Miscellaneous grass and grass-like plants			Trace	--	--	--	--	--	--	--	--	--	0.1	--	0.1	--	0.4	--	Trace	--
	Total grass		Trace		1.0		14.4		28.2		20.2		20.9		30.3		34.4		9.2	

* Miscellaneous and unidentified browse, forbs, and grass are those items bulking less than one percent of the total food in any monthly period.

TABLE 7

Supplemental List of Plants Eaten by Deer on the Lassen-Washoe Winter Range *

Scientific name	Common name	Frequency of occurence in percentage
Browse		
Libocedrus decurrens	Incense cedar	0.9
Ephedra viridis	Mormon tea	4.9
Populus tremuloides	Aspen	6.1
Sarcobatus vermiculatus	Black greasewood	0.3
Phoradendron villosum	Common mistletoe	0.3
Atriplex sp.	Saltbush	0.3
Berberis sp.	Barberry	0.6
Ribes velutinum	Plateau gooseberry	4.9
Amelanchier alnifolia	Service berry	1.8
Malus sp.	Cultivated apple	0.3
Robinia pseudoacacia	Locust	1.2
Arctostaphylos patula	Greenleaf manzanita	3.7
Nicotiana sp.	Wild tobacco	0.6
Symphoricarpos sp.	Snowberry	0.6
Chrysothamnus nauseosus	Rubber rabbitbrush	3.0
Unidentified browse		2.4
Forbs		
Bryophyta	Moss	0.6
Fungus	Mushroom	0.3
Equisetum sp.	Horsetail	2.1
Brodiaea sp.	Brodiaea	0.3
Liliaceae	Lily family	0.6
Lemna sp.	Duckweed	0.3
Eriogonum sp.	Wild buckwheat	6.7
Polygonum sp.	Smartweed	2.8
Polygonum aviculare	Wire grass	0.3
Rumex sp.	Dock	1.2
Chenopodium sp.	Goosefoot	1.5
Chenopodiaceae	Saltbush family	0.3
Salsola kali	Russian thistle	1.8
Amaranthus blitoides	Amaranth	0.6
Amaranthus sp.	Amaranth	0.6
Montia perfoliata	Miner's lettuce	0.3
Paeonia brownii	Western peony	0.6
Ranunculus sp.	Ranunculus	0.3
Lepidium sp.	Pepper grass	0.9
Sisymbrium altissimum	Tumbling mustard	0.9
Thysanocarpus sp.	Fringepod	0.3
Astragalus sp.	Rattle-weed	0.9
Lupinus sp.	Lupine	2.4
Medicago lupulina	Black medick	0.3
Medicago hispida	Bur clover	0.3
Trifolium sp.	Clover	0.6
Erodium sp.	Filaree	13.5
Malva sp.	Mallow	1.2
Cruciferae	Mustard family	0.3
Umbelliferae	Parsley family	0.3
Polemonium sp.	Jacob's ladder	0.3
Polemoniaceae	Gilia family	0.3
Amsinckia sp.	Fiddleneck	0.3
Pentstemon sp.	Pentstemon	0.9
Franseria acanthicarpa		0.3
Iva axillaris	Poverty weed	3.4
Eriophyllum lanatum		0.3
Madia sp.	Tarweed	0.6
Lactuca sp.	Wild lettuce	0.3
Monardella sp.		0.3
Unidentified Compositae	Sunflower family	0.6

TABLE 7—Continued

Supplemental List of Plants Eaten by Deer on the Lassen-Washoe Winter Range *

Scientific name	Common name	Frequency of occurence in percentage
Grass and grass-like plants		
Bromus mollis	Soft chess	0.3
Bromus tectorum	Cheat grass	57.2
Distichlis spicata	Salt grass	0.3
Hordeum sp.	Wild barley	1.5
Hordeum vulgare	Cultivated barley	0.3
Poa sp.	Blue grass	3.4
Carex sp.	Sedge	1.2
Eleocharis sp.	Spike rush	0.3
Cyperaceae	Sedge family	1.2
Juncus sp.	Rush	2.8

* Food items included in this list are those items which made up less than one percent of the total volume of food consumed in any monthly period.

food items bulking less than 0.1 percent during any monthly period. These data represent a compilation of the stomach analyses of deer collected in the winter months from 1949 through 1951-52. Figure 10 is a graphic representation of the 327 stomach analyses, showing the principal items of diet by month.

The seasonal utilization of forage on the Lassen-Washoe winter range is shown in Figure 10. It is apparent that the heavy utilization of bitterbrush, which is revealed by the annual forage utilization checks, occurs during the first four months that the deer occupy the winter range. The heaviest consumption of bitterbrush was in September and October, when it made up 60.2 and 62.3 percent of the diet and occurred in 100 and 85.2 percent of the stomachs examined.

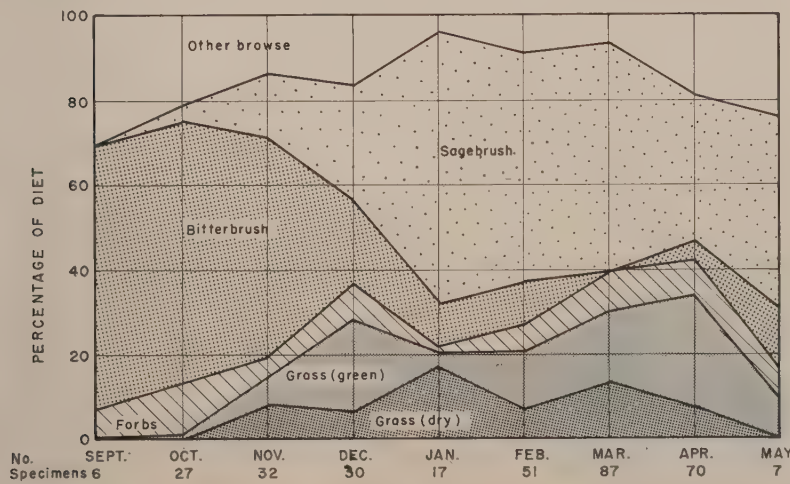

FIGURE 10. Graphic representation of the food habits of the Lassen-Washoe deer herd in the winters of 1948-49, 1949-50, 1950-51, and 1951-52.

The November diet again leaned heavily toward bitterbrush utilization, with bitterbrush found in 87.5 percent of the stomachs and contributing 51.6 percent to the diet. By December the consumption of bitterbrush had decreased to 20.5 percent and by January it amounted to only 10.0 percent of the food. This downward trend in bitterbrush consumption continued until March, when it was nonexistent in the diet of 87 deer examined. Deer resumed eating bitterbrush when the young leafage became available in late April and early May.

Although sagebrush was found in 51.9 percent of the stomachs examined, in October it contributed but 3.5 percent to the diet. By November the volume of sagebrush eaten had increased to 11.8 percent in 87.5 percent of the stomachs and in December had increased to 26.9 percent in 90.0 percent of the stomachs. The months of January, February, and March showed the heaviest consumption of sagebrush; it made up 64.9, 53.4, and 54.5 percent of the diets in these months and was found in over 94 percent of the stomachs. It continued to contribute materially to the diet in April (34.4 percent) and May (44.4 percent). Sagebrush may be considered the staple winter browse for deer on the Lassen-Washoe winter range.

Until snow forces the deer to the lower elevations of the winter range, they are able to utilize California black oak, curlleaf mountain mahogany, squaw carpet, snowbrush, and other browses which are available at the lower edges of the summer range. In mild, open winters these browses contribute to the diet in varying amounts throughout most of the winter for those deer wintering between Highway 395 and the Sierra Nevada. The fallen leaves and acorns of California black oak are eaten most heavily in September, October, and November, and are found in trace amounts in deer stomachs collected during other months of mild, open winters. However, this food item has a very restricted distribution and contributes very little to the over-all food of the Lassen-Washoe deer herd.

Curlleaf mountain mahogany, though eaten every month of the winter, contributed little to the diet except during the month of September, when 10.5 percent of the food consisted of this browse. The curlleaf mountain mahogany present on the range consists largely of mature plants which have been "high-lined" over a period of many years and is of little importance to the deer.

Squaw carpet and snowbrush contributed most to the diet in the early months of the winter. Choke cherry was utilized only in September and October, before the leaves are dropped. Occasionally, deer were found to have eaten the needles of ponderosa pine and white fir, which, during some months, contributed to the "other browse" eaten. Browse plants found in association with sagebrush and bitterbrush at the lower elevations of the winter range, and contributing to the diet, were willow, California wildrose, desert peach, juniper, and rabbitbrush. Willow, California wildrose, and desert peach are deciduous plants making up little of the food, and this for the most part in September and October. In the spring, when the young sprouting leafage becomes available, these plants are again utilized. This was especially true of desert peach, which apparently was eaten avidly in the early spring.

Juniper, although making up an estimated 1.3 percent of the vegetative composition, was used sparingly by the Lassen-Washoe deer herd. The highest volume of juniper eaten by these deer was in December, when it made up 1.2 percent of the volume of food and occurred in 16.7 percent of the stomachs. During the remainder of the winter months the amount of juniper eaten was negligible. Range observation by Dasmann and Blaisdell (1954) substantiates this, since they found little evidence of juniper utilization by deer. Why deer do not utilize juniper on the Lassen-Washoe winter range, as they do on the Devils Garden range, is not known.

Sticky-flowered rabbitbrush proved more acceptable to deer than rubber rabbitbrush. However, rabbitbrush was a minor part of the diet. The highest consumption was in December, when it constituted 1.3 percent of the diet and was found in 13.3 percen of the stomachs examined.

In contrast with the Devils Garden winter range, where annual and perennial forbs made up 17.3 percent of the vegetation, forbs on the Lassen-Washoe winter range made up only 3.7 percent. Of the forbs identified, alfalfa, sweet clover, hog-fennel, phlox, balsam root, and mule's ear contributed most to the diet. The contribution of alfalfa to the winter diet was the heaviest in February, March, and April, and may be credited to the collection of deer in the immediate vicinity of ranches. Alfalfa occurred infrequently, but made up a substantial bulk of the food of those deer in which it was found. During the early portion of the winter the leafage of sweet clover, balsam root, and mule's ear contributed the bulk of the forbs eaten. A list of the other forbs identified in the stomachs is included in Table 7.

Grass is an important item of diet of deer on the Lassen-Washoe winter range. Annuals form the bulk of the grass present and consist principally of cheat grass, which makes up 31.2 percent of the vegetative composition. With mild weather conditions, grass begins to grow with the early fall rains and is available to deer during the winter as long as the weather permits. The consumption of grass was negligible in October (1.0 percent), but increased to 14.4 and 28.2 percent, respectively, of the November and December diets. Grass continued to contribute heavily to the diet through the winter months to May. With the growth of new browse leafage in May, deer apparently eat less grass and consume more browse.

Climatic Conditions as They Affect Food Habits

As in the study of the Devils Garden herd, a breakdown of the stomach analyses has been made by individual winters. The following discussion is an attempt to relate yearly food habits of deer with weather fluctuations and to correlate this relationship with deer mortality and range conditions. Figures 11, 12, 13, and 14 are graphic representations of the trends in diet for the winters of 1948-49, 1949-50, 1950-51, and 1951-52. Climatic data taken at Doyle for temperature, precipitation, and snowfall during the winters of the above years may be found in the Appendix in Figures A-5, A-6, A-7, A-8, A-9, A-10, and A-11.

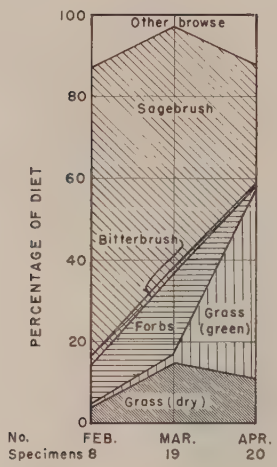

FIGURE 11. Graphic representation of the food habits of the Lassen-Washoe deer herd in the winter of 1948-49.

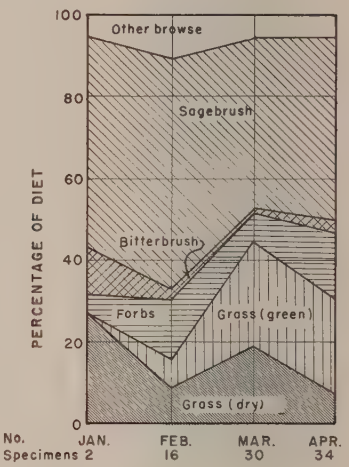

FIGURE 12. Graphic representation of the food habits of the Lassen-Washoe deer herd in the winter of 1949-50.

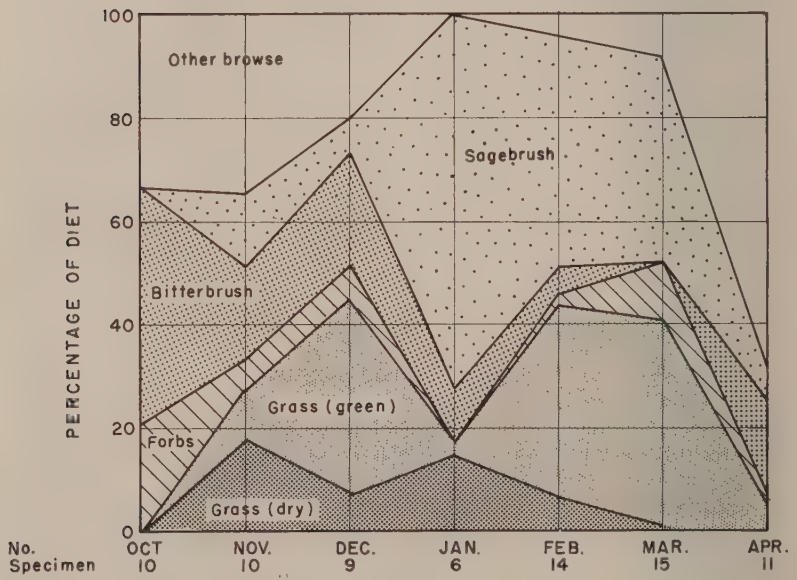

FIGURE 13. Graphic representation of the food habits of the Lassen-Washoe deer herd in the winter of 1950-51.

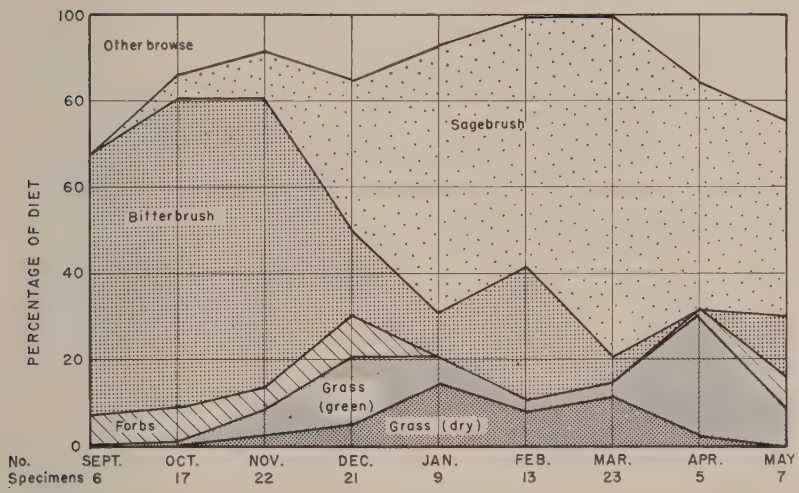

FIGURE 14. Graphic representation of the food habits of the Lassen-Washoe deer herd in the winter of 1951-52.

Winter of 1948-49

The winter of 1948-49 was the driest and one of the coldest in the sixty-year record of precipitation at Susanville, Lassen County (Upchurch and Brown, 1951). During the period October, 1948, through April, 1949, only 5.07 inches was recorded at Doyle, with 1.55 inches occurring in December and 1.24 inches in March, principally in the form of snow. Accompanying this period of snowfall in December was an abnormally low range of maximum and minimum temperatures. The lowest recorded monthly temperatures for the four years of study occurred in January and February of 1949, when —22 degrees F. and —24 degrees F. were recorded.

The intensive study of the Lassen-Washoe deer herd was initiated by the Department of Fish and Game and the Interstate Deer Herd Committee in 1949. Forty-seven stomach samples were collected from February through April of that year. Figure 11 is a graph showing the seasonal trend in diet over the three months of the initial collection.

Sagebrush formed the bulk of the diet, and was supplemented in April with green grass. The green grass apparently became available in April, as a result of warmer weather and increased precipitation. The grass eaten in February and March consisted principally of dry grass and it can be assumed that the low minimum temperatures of the previous months had inhibited any new growth. Bitterbrush contributed virtually nothing to the diet of the deer during the period from February through April. Ponderosa pine needles contributed a small part to the February diet and also occurred in the stomachs of the deer collected in March and April. By April, snowbrush and squaw carpet formed the bulk of the "other browse" eaten. The increased consumption of forbs in March was caused by alfalfa, which made up over 75 percent of the stomach contents in 6 of the 19 deer sampled.

Few data are available on the Lassen-Washoe deer herd for the winter of 1948-49. The winter of 1948-49 was the most critical of the four winters reported in this study. The range produced little additional feed to supplement the diet of sagebrush upon which the deer were forced to subsist. Robert Lassen, who in the fall of 1948 began to lay the groundwork for the study of the Lassen-Washoe deer herd, expressed the opinion that an extensive die-off of deer occurred and that it exceeded in magnitude the die-off which was to follow in the winter of 1949-50. This die-off in 1948-49 commenced in February and continued through April, as evidenced by the finding of numerous carcasses throughout the late winter. The deer observed were in noticeably poor condition. The discussion that follows on the effect of the cold, dry winter of 1949-50 on the deer can be assumed to apply also to the winter of 1948-49.

Winter of 1949-50

The winter of 1949-50 was a winter of low precipitation. During the period October through April only 5.61 inches were recorded at Doyle. Although the ranges in maximum and minimum temperatures were higher than those in 1948-49, the winter was cold and dry. Minus temperatures were recorded for December, January, and February. The precipitation, which began to fall in November, was for the most part rain, but in January 22.0 inches of snow were recorded.

Eighty-two stomach samples were collected from January through April, 1950; the results of the analyses are shown in Figure 12. Sagebrush formed the bulk of the late winter diet, contributing over 40 percent of the monthly intake of food. Bitterbrush, although contributing 11.0 percent to the diet in January, made up little of the bulk of foods eaten during the remaining months of the year. Other browses contributing to the diet were willow, aspen, California black oak, juniper, white fir, and ponderosa pine. Squaw carpet, snowbrush, and gooseberry made up the bulk of the "other browse" eaten in April. Grass contributed materially to the diet during this late winter period. Dry grass made up 27.5 percent of the January diet, but decreased in consumption as green grass became available. Green grass, although making up only 6.7 percent of the February diet, showed evidence of being heavily utilized in March (26.1 percent) and April (23.4 percent). Of the forbs contributing to the diet, alfalfa constituted the bulk, being found in 31 stomach samples of the 83 collected.

The winter of 1949-50 proved to be severe for deer wintering on the Lassen-Washoe winter range. Lassen et al., (1952), reporting on the condition of the deer herd, observed that the deer were generally in fair physical condition in January, but by March and April began to appear in very poor condition. The figures on fawn survivial derived from herd composition checks taken during the winter and early spring form an index of the severity of the 1950 die-off. The December, 1949, herd composition counts revealed 62 fawns: 100 does and only 12 fawns: 100 does in April, 1950. From these figures Lassen determined that 82 percent of the fawns had succumbed during the winter. The die-off was

attributed largely to malnutrition, following the examination of 213 deer carcasses for the degree of fat resorption. It is significant that a considerable die-off of deer occurred in the winter of 1949-50, following an extensive loss of deer during the previous winter.

Winter of 1950-51

The winter of 1950-51, in contrast with the two previous cold, dry winters, was mild and open. Precipitation amounted to 12.62 inches at Doyle, with the bulk of precipitation occurring in November, December, and January. Snowfall was light, falling principally in January, February, and March. The maximum and minimum temperatures were relatively high, with no minus temperatures recorded.

As in previous winters, sagebrush formed the bulk of the diet during the latter part of the winter. However, owing to the mild, open winter, it is evident that the deer were not as dependent upon sagebrush for food as they had been in previous years. The lower consumption of bitterbrush in the early part of the winter was perhaps influenced by the deer being able to utilize until January browses which normally are not available because of ground snow at the higher elevations. The deer were evidently able to remain until January along the lower edge of the summer range, where they fed on snowbrush, squaw carpet, California black oak, willow, and choke cherry. Due to the utilization of these other food plants, bitterbrush was available over a longer period of time, as evidenced by its contribution to the diet well into February. The heavy rains of October and November brought forth the growth of green grass, which contributed heavily to the diet throughout the winter except in January, when 6.5 inches of snowfall were recorded. However, little snow remained on the range and green grass again became available during February and March.

An abnormally early spring in April brought forth the growth of new browse leafage. The consumption of bitterbrush increased from nothing in March to 17.5 percent of the April diet. Seventy percent of the April diet consisted of browses other than bitterbrush and sagebrush. Of the other browses utilized, 91.0 percent was made up of the young leafage of desert peach and California wildrose. Forbs made up little of the diet, contributing the most in September and March. Alfalfa occurred in seven stomachs, making up most of the bulk of the forbs eaten in March. However the occurrence of alfalfa is likely to be reflected only in the sample taken in the vicinity of the ranches and contributes little to the diet of most of the deer in the herd.

The effect of the excellent forage conditions was evident in the condition of the deer wintering on the Lassen-Washoe range. The herd composition check made prior to the winter showed 49 fawns per 100 does, which was evidence that there had been poor fawn production and survival, possibly attributable to the previous critical winter. However, the survival of fawns over the favorable winter of 1950-51 was good. The spring herd composition revealed 48 fawns per 100 does. The range utilization check over the winter showed that bitterbrush had received less utilization by deer—34 percent of the current year's growth compared with 42 percent recorded for the previous

critical winter. This represents a drop in bitterbrush utilization of 24 percent from the figure given for the previous year.

A mild, open winter undoubtedly makes the bitterbrush available as food over a longer period of time, as well as subjecting it to less severe utilization, due to herd dispersal. Furthermore, other forages are available, lessening the pressure on the bitterbrush. In addition to the more favorable forage conditions and the mildness of the winter, consideration must be given to the fact that, due to the reduction in deer population brought about by the severity of the two previous winters, fewer deer were dispersed over the winter range.

Winter of 1951-52

During the early part of the winter of 1951-52 another mild and open winter was indicated. Rain had fallen during October and continued until January. Only 2.5 inches of snowfall had been recorded through January. However, there was a noticeable drop in temperature in December and severe snow storms began in January. Snowfall was extremely heavy in February, with 38 inches recorded at Doyle. An additional 9.0 inches fell in March, and 20.0 inches in April. Snow covered even the lower reaches of the winter range. This ground snow at the lower elevations disappeared rapidly. The winter, which earlier had given indications of being mild, suddenly became severe and critically affected the deer herd.

Sagebrush again contributed the bulk of the winter food, reaching a peak in consumption during January and March, when it constituted 62.2 and 77.0 percent of the diets. Bitterbrush accounted for 60.2 percent of the September diet and reached a high in October and November of 71.7 and 66.9 percent, respectively. The volume of bitterbrush decreased to 10.3 percent in January, but 31.6 percent of the February diet consisted of bitterbrush. The increased use of bitterbrush in February in comparison with previous years might be attributed to the heavy February snowfall, which enabled the deer to utilize some of the bitterbrush leaders that are normally out of reach. Other browses contributing to the diet from September through December were the following: squaw carpet, snowbrush, California wildrose, curlleaf mountain mahogany, California black oak, willow, and choke cherry. A little juniper and rabbitbrush was also utilized.

Following the October and November rains, grass began to contribute to the diet; green grass made up 15.3 percent of the December diet. However, in February and March the consumption of green grass amounted to only 2.8 and 3.3 percent of these monthly diets and it was not until April that a noticeable increase in the utilization of green grass (29.0 percent of the diet) occurred. Apparently, as the ground snow melted and green grass again became available, deer immediately began to utilize it. In May, bitterbrush and desert peach began to sprout new leafage, which contributed materially to the diet. Forbs made up little of the winter food, making their highest contribution to the diet in December (9.6 percent), when they consisted mostly of the dry leafage of mule's ear and balsam root. Alfalfa occurred in six of the 123 stomachs examined and was found only in the October samples.

A considerable die-off of deer occurred during the winter of 1951-52. A partial count of carcasses revealed 75 on approximately 760 acres. From the fawn : adult ratios of the December and April herd composition counts, it was calculated that the Lassen-Washoe deer herd had suffered a loss of 35 percent of the herd, consisting of 19 percent of the adults and 63 percent of the fawns (Lassen-Washoe Deer Herd Committee, 1952).

A further indication of the extent of the winter mortality is shown by comparing the fall and spring herd compositions. The fall count disclosed that 64 fawns per 100 does were present on the winter range in December, before the heavy snows occurred, while only 29 fawns per 100 does were present during the April count. This die-off of fawns was evidently not as extensive as that observed in 1949-50, when the spring herd composition count showed only 12 fawns per 100 does. It is worthy of note that, during the first part of the winter of 1951-52, the bitterbrush forage production was the highest of any year of the study. Dasmann and Blaisdell (1954) estimated that the 1951 production of bitterbrush forage was 54 percent greater than the average for the other three years of their study. Bitterbrush utilization amounted to 39 percent of the year's growth and it may be assumed that this utilization occurred, for the most part, during the first four months of this critical winter. Nevertheless, a considerable die-off of deer occurred.

Summer Food Habits

Table 8 is a summary of the food items eaten by 16 deer collected during the months of June through August. The locality of collection, which is typical summer range, was in the vicinity of the Dixie Refuge in Plumas County, California.

Browse plants made up 80.3 percent of the diet of the deer collected. Bitterbrush was the most important single item of diet; it contributed 34.6 percent and was found in 93.7 percent of the stomachs. Second in importance was snowbrush, which made up 22.8 percent of the summer diet and was found in 50.0 percent of the deer examined. Other important contributors to the browse diet, based on the amount eaten and the frequency of occurrence, were the following: greenleaf manzanita, curlleaf mountain mahogany, squaw carpet, willow, and aspen. Sagebrush, though found in 31.2 percent of the stomachs, failed to contribute any bulk to the diet.

Forbs, which contributed 19.6 percent to the summer diet, consisted principally of phlox, mule's ear, wild buckwheat, lupine, and unidentified herbaceous leafage.

Grass made up only 0.1 percent of the summer diet, although it was found in 50.0 percent of the stomachs.

An analysis of the summer food habits is limited by the small sample of deer stomachs. It is significant that the three heaviest contributors to the diet—bitterbrush, snowbrush, and greenleaf manzanita—are the browses which are most abundantly distributed on the summer range. Forbs are apparently taken in greater bulk than are grasses. Grass consumption was negligible, although grass was readily available in open meadows in the immediate vicinity of the collection area.

TABLE 8

Summary of Food Items Eaten by 16 Rocky Mountain Mule Deer Collected From the Summer Range of the Lassen-Washoe Deer Herd, Expressed in Percentages *

Scientific name	Common name	Volume	Frequency
Browse			
Purshia tridentata	Bitterbrush	34.6	93.7
Ceanothus velutinus	Snowbrush	22.8	50.0
Arctostaphylos patula	Greenleaf manzanita	9.9	43.1
Cercocarpus ledifolius	Curlleaf mountain mahogany	4.6	56.2
Salix sp.	Willow	3.8	18.7
Ceanothus prostratus	Squaw carpet	3.0	50.0
Populus tremuloides	Aspen	0.9	6.2
Arceuthobium campylopodium	Pine mistletoe	0.4	25.0
Quercus kelloggii	Black oak	0.1	6.2
Prunus sp.	Wild cherry	0.1	6.2
Prunus demissa	Choke cherry	0.1	13.5
Pinus ponderosa	Yellow pine	Trace	62.5
Librocedrus decurrens	Incense cedar	Trace	6.2
Rosa californica	California wild rose	Trace	6.2
Amelanchier alnifolia	Western service berry	Trace	6.2
Artemisia tridentata	Sagebrush	Trace	31.2
Unidentified browse		Trace	6.2
	Total browse	80.3	
Forbs			
Phlox sp.	Phlox	7.9	37.5
Ranunculus californica	Buttercup	4.7	13.5
Wyethia sp.	Mule-ears	4.4	31.2
Eriogonum sp.	Wild buckwheat	2.0	25.0
Paeonia brownii	Western peony	0.4	18.7
Lupinus sp.	Lupine	0.1	43.1
Fungus	Mushroom	Trace	6.2
Scirpus sp.	Bulrush	Trace	6.2
Polygonum sp.	Knotweed	Trace	13.5
Montia perfoliata	Miner's lettuce	Trace	25.0
Ranunculus sp.	Buttercup	Trace	13.5
Collomia sp.	Collomia	Trace	18.7
Collinsia sp.	Chinese houses	Trace	18.7
Pentstemon sp.	Pentstemon	Trace	6.2
Pentstemon deustus	Pentstemon	Trace	6.2
Taraxacum sp.	Dandelion	Trace	6.2
Unidentified Compositae	Sunflower family	Trace	18.7
Unidentified forbs		0.1	68.7
	Total forbs	19.6	
Grass			
Gramineae (green)	Grass family	0.1	50.0
Poa sp.	Blue grass	Trace	13.5
Bromus tectorum	Cheat grass	Trace	13.5
Bromus sp.	Brome grass	Trace	13.5
	Total grass	0.1	

* Collection of deer made as follows: 5 in May, 6 in June, 2 in July, and 3 in August. Locality of collection: east and west of Dixie Refuge, Plumas County, California.

SIERRA VALLEY DEER HERD (VERDI SECTION)

Description of Area

The Verdi study area is located in Truckee River Canyon at the California-Nevada border, just west of the town of Verdi, Nevada (Figure 1). This small area was selected because it was thought to represent a bitterbrush range in good condition, typical of the zone of transition between the sagebrush climax and the pine forest type. There is considerable use of areas of this type by deer during the early

part of every winter and throughout open winters. As an intermediate winter range, forage conditions in the study area are considered to be the best of all the winter ranges represented in this study (Figure 15).

The range composition for the Verdi study area, as determined by 76-milacre plots, is given in Table 9. Because only a small portion of the Verdi winter range was sampled, the vegetative composition is not representative of the entire range. However, it will serve as an index for comparison with data on other winter ranges.

An examination of Table 9 shows bitterbrush to be more abundant than sagebrush, with the two species making up 67.9 percent of the ground cover.

The ratio of dead to living browse on the Verdi study area is 1:25 for bitterbrush and 1:33.3 for sagebrush. Comparative figures for the Lassen-Washoe range are 1:3 for bitterbrush and 1:3.4 for sagebrush. In addition, 30 percent of the Verdi bitterbrush stand consists of seedlings and young plants, which are sparsely represented on the Lassen-Washoe range.

TABLE 9

Percentage Composition of Browse Vegetation of the Verdi Study Area

		Percentage composition per average acre
Purshia tridentata	Bitterbrush	37.9
Artemisia tridentata	Sagebrush	30.0
Chrysothamnus nauseosus	Rubber rabbitbrush	10.3
Arctostaphylos patula	Greenleaf manzanita	7.9
Ceanothus velutinus	Snowbrush	1.8
Cercocarpus ledifolius	Curlleaf mountain mahogany	1.2
Prunus andersonii	Desert peach	0.9
Pinus ponderosa	Ponderosa pine	0.9
Salix sp.	Willow	0.6
Ribes sp.	Gooseberry	0.3
Libocedrus decurrens	Incense cedar	0.3
Other browse		4.1
Purshia tridentata (dead)		1.4
Artemisia tridentata (dead)		0.9
Chrysothamnus nauseosus (dead)		0.6
Ceanothus velutinus (dead)		0.9

Ground Cover Classification
(Excluding above browse)

	Percentage of plots
Grass	46.1
Bare	28.9
Litter	18.4
Rock	5.3
Squaw carpet	1.3
Forbs	0.0

TABLE 10

Summary of the Food Eaten by 36 Rocky Mountain Mule Deer Collected From the Verdi Study Area, California, Calendar Year of 1951, Expressed in Percentages

Scientific name	Common name	Number of specimens	January		February		April		May		September		November		December	
			6		5		5		5		5		5		5	
			Volume	Frequency	Volume	Frequency	Volume	Frequency	Volume	Frequency	Volume	Frequency	Volume	Frequency	Volume	Frequency
Browse																
Libocedrus decurrens	Incense cedar		Trace	83.3	3.0	20.0	--	--	Trace	20.0	-	-	Trace	40.0	1.4	60.0
Pinus ponderosa	Ponderosa pine		Trace	33.3	Trace	20.0	Trace	40.0	Trace	60.0	Trace	40.0	Trace	40.0	Trace	20.0
Salix sp.	Willow		--	--	--	--	--	--	--	--	8.6	60.0	--	--	--	--
Populus tremuloides	Aspen		Trace	16.7	--	--	--	--	--	--	--	--	--	--	--	--
Ribes sp.	Gooseberry		--	--	--	--	--	--	--	--	0.4	60.0	--	--	--	--
Arceuthobium campylopodium	Pine mistletoe		0.3	16.7	--	--	--	--	--	--	--	--	--	--	--	--
Purshia tridentata	Bitterbrush		23.4	83.3	25.8	100.0	3.2	40.0	60.6	100.0	34.8	40.0	40.6	80.0	15.0	100.0
Prunus demissa	Choke cherry		--	--	--	--	--	--	--	--	14.0	40.0	--	--	--	--
Prunus andersonii	Desert peach		--	--	--	--	--	--	2.0	20.0	--	--	--	--	--	--
Cercocarpus ledifolius	Curlleaf mountain mahogany		Trace	66.6	Trace	100.0	Trace	40.0	Trace	20.0	Trace	40.0	6.6	60.0	7.0	80.0
Amelanchier alnifolia	Service berry		--	--	--	--	-	-	--	--	Trace	20.0	--	--	--	--
Ceanothus velutinus	Snowbrush		2.5	16.6	--	--	10.0	60.0	Trace	20.0	33.8	100.0	6.6	80.0	21.0	40.0
Ceanothus prostratus	Squaw carpet		15.8	100.0	2.0	40.0	4.0	100.0	7.0	80.0	6.0	60.0	10.8	100.0	0.4	40.0
Arctostaphylos patula	Greenleaf manzanita		13.5	83.3	13.0	80.0	44.8	80.0	Trace	40.0	--	--	Trace	40.0	53.8	100.0
Chrysothamnus nauseosus	Rubber rabbitbrush		--	--	--	--	--	--	--	--	--	--	Trace	20.0	--	--
Chrysothamnus viscidiflorus	Rabbitbrush		--	--	--	--	--	--	Trace	20.0	--	--	--	--	--	--
Artemisia tridentata	Sagebrush		16.8	100.0	35.2	80.0	18.6	100.0	21.6	80.0	Trace	20.0	9.8	100.0	1.0	60.0
	Total browse		72.3		79.0		80.6		91.2		97.6		74.4		99.6	
Forbs																
Fungus	Mushroom		--	--	Trace	20.0	--	--	--	--	--	--	--	--	--	--
Polypodiaceae	Fern		Trace	16.7	--	--	--	--	--	--	--	--	--	--	--	--
Eriogonum sp.	Buckwheat		Trace	33.3	--	--	--	--	--	--	--	--	--	--	--	--
Platyspermum scapigerum			--	--	--	--	Trace	20.0	--	--	--	--	--	--	--	--
Sisymbrium altissimum	Tumbling mustard		--	--	--	--	--	--	--	--	Trace	20.0	--	--	-	--

Erodium sp.	Filaree	--	--	Trace	20.0	--	--	--	--	--	--	--	--	--	--
Cryptantha sp.	Nievitas	--	--	--	--	--	--	--	--	Trace	20.0	--	--	--	--
Pentstemon sp.	Pentstemon	--	--	--	--	--	--	--	--	0.4	20.0	--	--	--	--
Cirsium sp.	Thistle	Trace	16.7	--	--	--	--	--	--	--	--	--	--	--	--
Wyethia mollis	Mule-ears	--	--	--	--	--	--	Trace	20.0	--	--	1.2	60.0	--	--
Unidentified compositae		Trace	16.7	--	--	--	--	--	--	--	--	--	--	--	--
Unidentified forbs		Trace	33.3	--	--	--	--	1.4	80.0	2.0	40.0	Trace	20.0	Trace	20.0
	Total forbs							1.4		2.4		1.2			
Grass and grass-like plants															
Gramineae (dry)	Grass family	10.2	100.0	11.6	100.0	Trace	60.0	--	--	Trace	40.0	22.8	100.0	0.4	40.0
Gramineae (green)	Grass family	17.5	100.0	9.4	100.0	19.4	100.0	7.4	100.0	Trace	60.0	1.6	100.0	Trace	20.0
Bromus tectorum (florets)	Cheat grass	Trace	50.0	Trace	20.0	Trace	60.0	--	--	Trace	20.0	Trace	20.0	--	--
Poa sp. (florets)	Blue grass	--	--	--	--	--	--	Trace	20.0	--	--	--	--	--	--
Carex sp.	Sedge	--	--	--	--	--	--	--	--	--	--	--	--	Trace	20.0
	Total grass	27.7		21.0		19.4		7.4				24.4		0.4	

FIGURE 15. The Verdi study area, showing the principal vegetative types. The bitterbrush-sagebrush association in the foreground gives way to a snowbrush-greenleaf manzanita association, interspersed with ponderosa pine forest, covering the slopes. *Photograph by the author.*

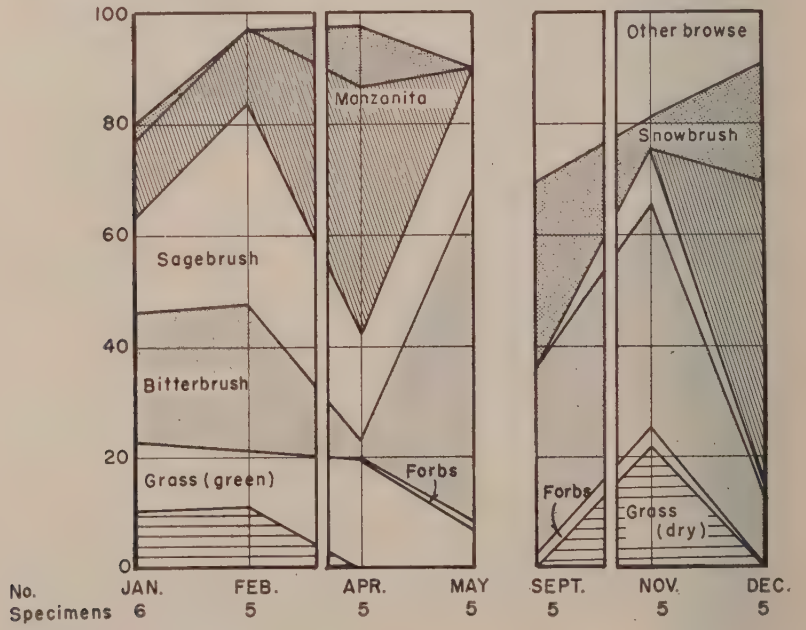

FIGURE 16. Graphic representation of the food habits of deer collected from the Verdi study area in the calendar year 1951.

Food Habits

Table 10 is a monthly summary of the food items eaten by 36 deer collected during the calendar year 1951 from the Verdi study area. No deer were collected during the summer months or during March and October.

It is evident from an examination of both Table 10 and Figure 16 that the deer inhabiting this section of the winter range utilize a number of browse species throughout the winter months. This resulted in a diet varying markedly from month to month.

Of particular interest is the monthly utilization of bitterbrush contrasted with that on the Lassen-Washoe and Devils Garden winter ranges. Bitterbrush contributed materially to the diet over most of the winter months with the exception of April. Had a March sample of deer been collected, it might have revealed a possible low utilization of bitterbrush, as in April. This was found to occur on all the other deer ranges reported in the study and could not always be attributed to the unavailability of bitterbrush forage.

Sagebrush was an important contributor to the diet only in the late winter months. The greatest use of this plant was in February, when it made up 35.2 percent of the diet and occurred in 80.0 percent of the stomachs. No collecting was done in March, but continued utilization of sagebrush was noted in April and May. Greeenleaf manzanita contributed materially to the diet during January, February, and April and made up 53.8 percent of the December diet, occurring in 100 percent of the stomachs. Snowbrush made up 10.0 percent of the April, 33.8 percent of the September, and 21.0 percent of the December diets, but contributed little over the remaining months studied. Other browse found in the winter diet are listed in Table 10.

Forbs contributed little to the food of deer collected in the Verdi study area. In January green grass apparently became available and both green and dry grass were found in the diet over the remainder of the winter months. Grass, although eaten in bulk in November (24.4 percent), consisted almost entirely of dry matter.

It should be pointed out that, because of the small, localized sample, the data presented here for the Verdi study area are not representative of the entire Loyalton-Truckee deer herd subunit. Had deer stomachs been sampled throughout the winter months from January to April of 1952, probably an entirely different food habits picture would have resulted. January and February produced the same record snowfall and critical conditions experienced by other Great Basin deer herds. Deer wintering in Truckee Canyon were driven out of the upper reaches of this winter range and forced to subsist in its lower, eastern areas.

INYO DEER HERD

Description of Area

Most of the winter range of the Inyo mule deer is in Owens Valley, Inyo County, California. This valley is an elongated basin some 85 miles long, situated between the Sierra Nevada and the White-Inyo mountain ranges, which rise abruptly to over 14,000 feet. From the base of the mountains, huge alluvial fans, occasionally interrupted by lava flows and low hills of volcanic origin, slope into the valley. The

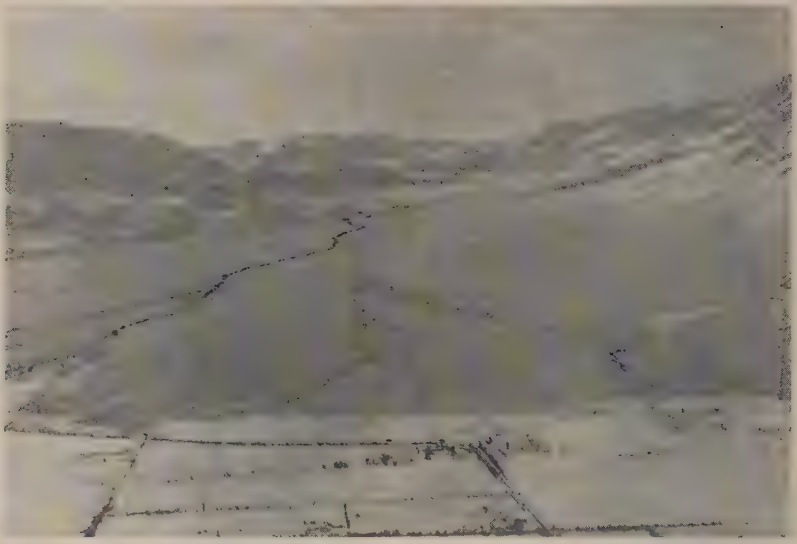

FIGURE 17. Aerial photograph of the Buttermilk winter deer range in Inyo County, showing the extensive piedmont plain descending to the valley floor. *Photograph by Fred Jones, January, 1952.*

FIGURE 18. A typical view of the vegetative composition of the Buttermilk winter deer range. Bitterbrush, sagebrush, and blackbush make up the vegetation in the foreground, while piñon pine grows on the lower slopes in the background. *Photograph by C. M. Ferrel.*

valley averages 10 to 15 miles wide and its floor slopes from 4,300 feet at the northern end to 3,000 feet near Little Lake at the southern end.

Most of the winter range of the Inyo mule deer occurs on the west side of Owens Valley along the base of the Sierra Nevada (Figures 17 and 18). It is restricted to approximately 166,000 acres. During the summer these deer are confined generally to the western slope of the Sierra Nevada, which they reach through numerous passes, some over 11,000 feet high. This extensive summer range of some 598,000 acres is almost entirely within Kings Canyon and Sequoia National Parks and Inyo National Forest.

Vegetative Composition of the Range

The sagebrush formation, with which the distribution of the Rocky Mountain mule deer in California is closely associated, comprises the dominant vegetation found on the winter range of the Inyo mule deer. This sagebrush climax intergrades with desert shrub vegetative types at the lower elevations. At the southern extremity of Owens Valley is the more arid Mojave Desert climax, which is dominated by creosote bush (*Larrea tridentata*). Because of the diversity in plant associations occurring on the winter range of the Inyo deer herd, the available stomach samples were divided into two groups. One represents the food habits of the deer inhabiting the northern Inyo-Sierra winter ranges, while the other represents that of deer on the southern Inyo-Sierra winter ranges.

Northern Inyo

The Northern Inyo samples include stomachs collected from the winter ranges along the base of the Sierra Nevada from Sherwin Summit, northwest of Bishop, to Piñon Creek, west of Independence. The winter range includes the steep, lower mountain slopes and the gentle eastwardly descending alluvial fans, sloping from 6,000 feet at the base of the mountains to 4,000 feet at the valley floor. The more elevated winter range, which is superior to the lower range, is dominated by sagebrush and bitterbrush,[4] with an association of desert ceanothus, desert peach, California buckwheat, ephedras, and numerous species of bunch grass dominated by needlegrass, Indian rice grass, and wild rye. Piñon pine occurs on the highest parts of the winter range. The lower edges and the southern extremity of this range are characterized by extensive areas of sagebrush, blackbush, and rabbitbrushes. There is an intermingling of the more arid-growing browse plants like dalea (*Dalea* sp.), fourwing salt brush, and white burrobrush. The numerous creeks which descend into the valley are lined with willow, water birch, and introduced locust. Small meadows are interspaced throughout the winter range.

The vegetative composition of the Buttermilk area, which is typical of the northern Inyo range, is based on 62 line-point plots (Table 11).

Southern Inyo

The sampling of deer stomachs from the southern Inyo winter ranges included those taken between Sage Flat, southwest of Olancha, and

[4] Two species of bitterbrush (*Purshia tridentata* and *P. glandulosa*) occur in Owens Valley, but because of the difficulty in distinguishing the two species by leafage characteristics all bitterbrush is designated as *P. tridentata* in this report.

TABLE 11

Percentage Composition of Vegetation on the Buttermilk Winter Range

Grass		
Annual grasses		0.6
Perennial grasses		7.2
Total grass		7.8
Forbs		
Annual forbs		5.3
Perennial forbs		1.3
Total forbs		6.6
Browse		
Artemisia tridentata	Sagebrush	29.4
Ceanothus greggii	Desert ceanothus	3.0
Chrysothamnus spp.	Rabbitbrush	3.0
Coleogyne ramosissima	Blackbush	12.5
Ephedra sp.	Ephedra	3.6
Eriogonum spp.	Wild buckwheat	2.8
Grayia spinosa	Spiny hop-sage	trace
Haplopappus sp.	Goldenbush	0.3
Prunus andersonii	Desert peach	2.0
Purshia tridentata	Bitterbrush	26.7
Rosa spp.	Wild rose	1.0
Salix spp.	Willow	trace
Tetradymia spp.	Horsebrush	1.0
Other browse		0 3
Total browse		85.6
Percentage of ground covered by productive forage		30.0

Fines Canyon, southwest of Dunmovin. The winter range used by the deer is largely restricted to the lower mountain slopes, with little use made of the piedmont plain, except in critical winters. Representative of the southern Inyo winter range is Tunawee Canyon, which is about 1½ miles in length and embraces some 1,500 acres of accessible winter range (Figure 19). There are two definite slope exposures: the south-facing slopes are sparsely vegetated with narrow leaf goldenbrush (*Haplopappus linearifolius*), snakeweed, burrobrush, and California buckwheat; the more heavily wooded, north-facing slopes are covered with bitterbrush, sagebrush, and rabbitbrush, interspersed with canyon oak and piñon pine. Willow grows extensively along the creek bottoms.

Table 12 gives the vegetative composition of the Tunawee winter range based on 19 line-point plots.

Migration

Fall migration of the Inyo mule deer generally begins in the latter part of September and continues until November, when the bulk of the deer are on the winter range. Deer summering on the western slope of the Sierra Nevada follow prominent migration routes over the crest and make an abrupt descent to the winter range. The spring migration begins in April and is completed by July, with the deer returning to the summer range over the same migration routes. An estimate of the winter deer population of the entire Inyo deer herd unit is not available for 1951-52, but Jones (1954) estimated the 1954 population at 26,900.

FIGURE 19. Tunawee Canyon in southern Inyo County, showing the abruptness of the terrain and the difference in vegetative composition between the north and south facing slopes. *Photograph by Fred Jones.*

TABLE 12

Percentage Composition of Vegetation on the Tunawee Winter Range

Grass		
Annual grasses		2.3
Perennial grasses		5.2
Total grass		7.5
Forbs		
Annual forbs		9.3
Perennial forbs		0.2
Total forbs		9.5
Browse		
Artemisia tridentata	Sagebrush	23.0
Ceanothus greggii	Desert ceanothus	1.9
Chrysothamnus spp.	Rabbitbrush	14.9
Ephedra sp.	Ephedra	9.0
Eriogonum sp.	Wild buckwheat	5.2
Guiterrezia sp.	Snakeweed	1.4
Haplopappus linearifolium	Narrow-leaf goldenbush	3.3
Hymenoclea salsola	White burrobrush	5.2
Lupinus sp.	Lupine	1.2
Malvastrum sp.	Globemallow	0.7
Purshia tridentata	Bitterbrush	4.3
Prunus andersonii	Desert peach	2.1
Ribes sp.	Gooseberry	2.1
Tetradymia spinosa	Horsebrush	4.7
Other browse		4.0
Total browse		83.0
Percentage of ground covered by productive forage		22.4

TABLE 13

Summary of the Food Items Eaten by 160 Inyo Mule Deer Collected From the Northern Inyo Winter Ranges in Winter of 1951-52, Expressed in Percentages

Scientific name	Common name	Number of specimens	December 21		January 26		February 60		March 29		April 24	
			Volume	Frequency	Volume	Frequency	Volume	Frequency	Volume	Frequency	Volume	Frequency
Browse												
Pinus cembroides	Piñon pine		--	--	--	--	0.7	3.3	--	--	--	--
Pinus ponderosa	Yellow pine		--	--	Trace	3.8	--	--	--	--	--	--
Ephedra viridis	Green ephedra		--	--	0.2	19.2	0.1	28.3	0.2	27.6	Trace	8.3
Populus sp.	Poplar		--	--	--	--	0.5	13.3	--	--	--	--
Betula fontanalis	Water birch		Trace	4.8	2.8	11.5	3.7	20.0	1.0	6.9	--	--
Salix sp.	Willow		0.5	4.8	0.2	15.3	3.0	36.7	Trace	3.4	0.1	4.2
Quercus chrysolepis	Canyon oak		--	--	--	--	0.6	1.7	--	--	--	--
Eriogonum fasciculatum	California buckwheat		--	--	--	--	1.4	20.0	1.6	6.9	Trace	12.5
Atriplex canescens	Fourwing saltbush		1.5	4.8	Trace	7.7	0.1	6.7	--	--	0.2	8.3
Rosa californica	California wild rose		--	--	Trace	3.8	Trace	1.7	--	--	1.0	12.5
Cercocarpus ledifolius	Curlleaf mahogany		--	--	0.1	3.8	--	--	--	--	--	--
Coleogyne ramosissima	Blackbush		8.2	66.7	15.3	80.8	26.8	73.3	15.3	75.9	10.1	41.7
Purshia tridentata	Bitterbrush		38.1	81.0	7.9	57.7	2.7	18.3	2.0	51.7	7.9	75.0
Prunus andersonii	Desert peach		--	--	Trace	3.8	Trace	1.7	--	--	2.6	45.8
Ceanothus greggii	Desert ceanothus		Trace	4.8	Trace	3.8	0.6	5.0	Trace	3.4	Trace	8.3
Chrysothamnus teretifolius	Rabbitbrush		--	--	Trace	11.5	3.9	48.3	6.2	13.7	--	--
Chrysothamnus nauseosus	Rubber rabbitbrush		--	--	Trace	7.7	--	--	--	--	Trace	4.2
Artemisia tridentata	Sagebrush		50.3	100.0	73.5	96.1	51.2	95.0	71.4	93.1	48.3	100.0
Robinia pseudoacacia	Locust		Trace	4.8	Trace	3.8	2.3	13.3	Trace	13.8	--	--
Unidentified browse			--	--	--	--	Trace	1.7	--	--	--	--
	Total browse		98.6		100.0		97.6		97.7		70.2	
Forbs												
Bryophyta	Moss		--	--	--	--	--	--	Trace	3.4	--	--
Polypodiaceae	Fern		--	--	--	--	Trace	3.3	--	--	--	--
Brodiaea sp.	Brodiaea		--	--	--	--	--	--	--	--	1.1	46.8

Liliaceae	Lily family	--	--	--	--	--	--	Trace	3.4	Trace	8.3
Eriogonum sp.	Buckwheat	Trace	9.5	--	--	--	--	Trace	3.4	0.1	25.0
Rumex sp.	Dock	--	--	--	--	0.3	1.7	--	--	--	--
Lupinus sp.	Lupine	--	--	--	--	Trace	3.3	--	--	Trace	21.0
Lomatium sp.	Hog fennel	--	--	--	--	--	--	--	--	12.7	33.3
Unidentified forbs		Trace	4.8	Trace	3.8	Trace	5.0	Trace	13.8	8.2	70.8
	Total forbs					0.3				22.1	
Grass and grass-like plants											
Gramineae (green)	Grass family	0.9	9.5	--	--	1.0	13.3	1.6	62.1	7.7	87.5
Gramineae (dry)	Grass family	0.5	14.3	Trace	26.9	1.1	33.3	0.6	41.4	Trace	4.2
Bromus tectorum (florets)	Cheat grass	--	--	Trace	7.7	Trace	3.3	--	--	--	--
Cyperaceae	Sedge family	--	--	Trace	7.7	--	--	Trace	3.4	--	--
Juncus sp.	Rush	--	--	--	--	Trace	1.7	0.1	6.9	--	--
	Total grass and grass-like plants	1.4				2.1		2.3		7.7	

Food Habits

Table 13 is a monthly summary of the food items eaten by 160 deer collected on the northern Inyo deer ranges during the period from December, 1951, to April, 1952, and Figure 20 is a graphic representation of this diet.

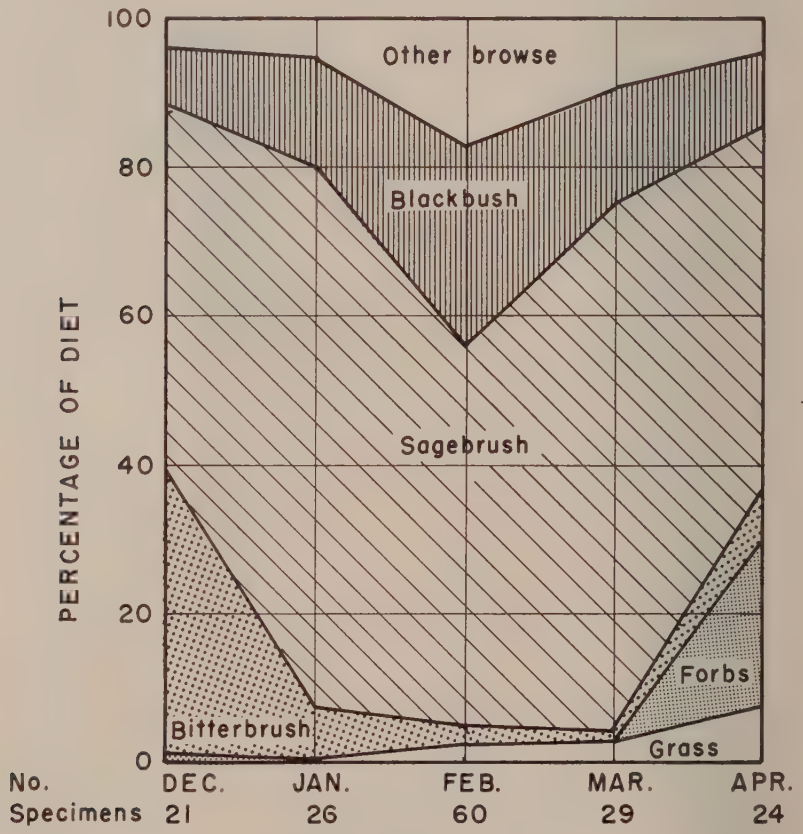

FIGURE 20. Graphic representation of the food habits of deer on the northern Inyo winter ranges in the winter of 1951-52.

The staple item of diet for the northern Inyo deer during the late winter months of 1951-52 proved to be sagebrush. It occurred in 96.9 percent of the stomachs and made up 64.2 percent of the diet during the period from December through April. The heaviest consumption of sagebrush was in January and March. Second to sagebrush in the diet of these deer was blackbush, commonly found associated with sagebrush at the lower elevations of the winter range. Its highest contribution to the diet was in February, when it made up 26.8 percent of the diet in 73.3 percent of the stomachs. Bitterbrush, although bulking 38.1 percent of the December diet in 81.0 percent of the stomachs, contributed little to

the food during the remaining months of the winter. A number of other browse plants supplemented the basic diet of sagebrush, blackbush, and bitterbrush. Forbs and grass were of little importance in the over-all winter diet, apparently becoming available only in April, when young forbs contributed 22.1 percent and green grass 7.7 percent to the diet.

The only stomach samples available from the northern Inyo winter ranges were those collected in the severe late winter months of 1951-52,

TABLE 14

Summary of the Food Items Eaten by 91 Inyo Mule Deer Collected from the Southern Inyo Winter Ranges in Winter of 1952, Expressed in Percentages

Scientific name	Common name	Number of specimens	January 45		February 30		March 16	
			Volume	Frequency	Volume	Frequency	Volume	Frequency
Browse								
Pinus cembroides	Piñon pine		19.8	48.9	9.2	40.0	2.5	18.8
Juniperus sp.	Juniper		Trace	2.2	--	--	--	--
Ephedra viridis	Green ephedra		Trace	17.8	0.3	36.7	1.3	6.3
Populus sp.	Poplar		--	--	0.2	3.3	--	--
Betula fontinalis	Water birch		0.1	2.2	--	--	--	--
Salix sp.	Willow		12.9	48.9	15.2	50.0	12.5	37.5
Quercus chrysolepis	Canyon oak		13.8	62.2	9.7	36.7	1.9	6.3
Eriogonum fasiculatum	California buckwheat		5.0	57.8	0.9	26.7	2.4	50.0
Atriplex conferifolia	Sheep-fat		1.0	15.6	0.8	30.0	0.6	31.3
Atriplex canescens	Fourwing saltbush		--	--	--	--	1.3	6.3
Coleogyne ramosissima	Blackbush		4.2	17.8	--	--	Trace	6.3
Purshia tridentata	Bitterbrush		3.9	46.7	0.7	30.0	--	--
Prunus andersonii	Desert peach		Trace	2.2	Trace	3.3	--	--
Rhamnus californica	California coffee berry		--	--	2.4	10.0	Trace	6.3
Ceanothus greggii	Desert ceanothus		0.1	8.9	2.0	23.3	--	--
Salvia sp.	Sage		Trace	2.2	2.3	16.7	Trace	12.5
Artemisia tridentata	Sagebrush		10.5	57.8	30.9	83.3	29.7	62.3
Chrysothamnus teretifolius	Rabbitbrush		27.1	84.4	24.1	73.3	46.2	100.0
Tetradymia sp.	Horsebrush		0.4	2.2	--	--	--	--
Robinia pseudoacacia	Locust		Trace	2.2	--	--	--	--
Unidentified browse			--	--	0.9	3.3	--	--
	Total browse		98.8		99.6		98.4	
Forbs								
Polypodiaceae	Fern family		Trace	2.2	0.2	10.0	0.2	12.5
Eriogonum sp.	Wild buckwheat		--	--	--	--	Trace	6.3
Brodiaea sp.	Brodiaea		--	--	--	--	Trace	6.3
Lupinus sp.	Lupine		Trace	2.2	Trace	3.3	Trace	12.5
Compositae	Sunflower family		--	--	Trace	3.3	--	--
Unidentified forbs			Trace	11.1	Trace	13.3	0.3	6.3
	Total forbs		--		0.2		0.5	
Grass and grass-like plants								
Gramineae (green)	Grass family		Trace	20.0	Trace	3.3	0.5	68.8
Gramineae (dry)	Grass family		1.2	22.2	Trace	23.3	0.6	18.8
Bromus sp. (florets)	Brome grass		Trace	4.4	Trace	3.3	Trace	6.3
Carex sp.	Sedge		Trace	2.2	--	--	--	--
Cyperaceae	Sedge family		--	--	0.2	3.3	--	--
	Total grasses and grass-like plants		1.2		0.2		1.1	

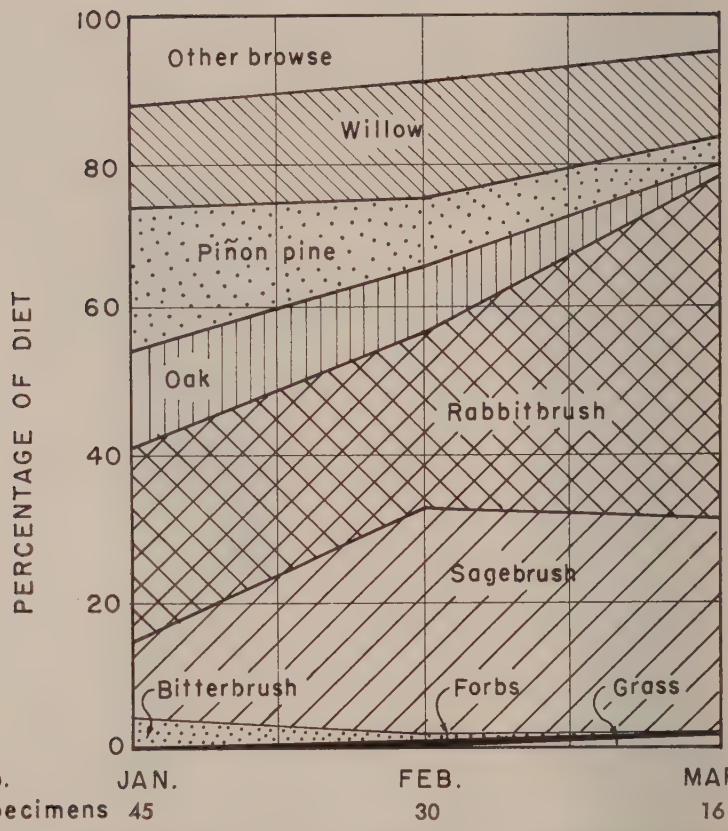

FIGURE 21. Graphic representation of the food habits of deer on the southern Inyo winter ranges in the winter of 1951-52.

precluding comparison of these food habits data with those from a mild winter.

The 112 stomach samples from the southern Inyo winter ranges were taken from 91 winter-killed deer collected in 1952, and 21 deer collected from the Tunawee winter range by shooting during the late months of the mild winter of 1952-53. Table 14 and Figure 21 represent the food habits of the Inyo mule deer inhabiting the southern Inyo deer ranges during the severe winter months of January through March, 1952. Representative of the food habits of the deer in the same period of a mild, open winter is the Tunawee collection of 21 deer made in February, March, and April, 1953, and shown in Table 15 and Figure 22.

The two most important items contributing to the diet of the deer on the southern Inyo winter ranges during the critical late winter months of 1952 were rabbitbrush and sagebrush. Rabbitbrush (*Chrysothamnus teretifolius*), which dominates the lower reaches of the Tuna-

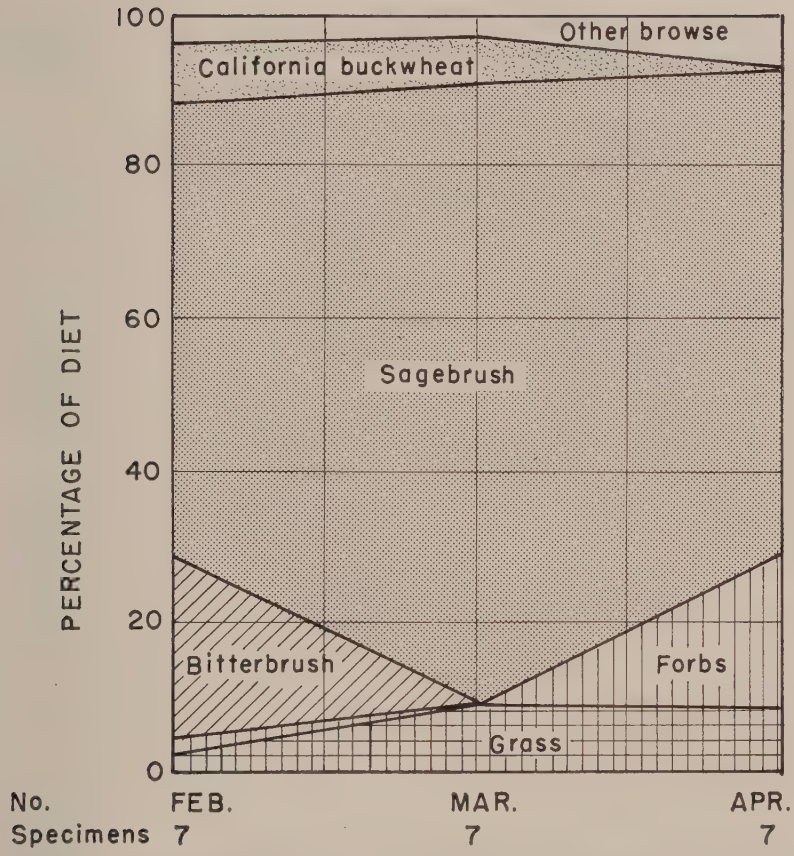

FIGURE 22. Graphic representation of the food habits of deer on the Tunawee winter range in the winter of 1952-53.

wee range, was the heaviest contributor to the diet, making up 29.5 percent of the food and occurring in 83.5 percent of the stomachs during the late winter months. The heavy utilization of rabbitbrush in March (46.2 percent) coincides with the month of heaviest snowfall, during which the deer were forced to the lowest elevations of the winter ranges. The consumption of sagebrush over the winter amounted to 20.5 percent of the diet and was found in 67.0 percent of the stomachs. Heaviest use was in February and March. Before the severe snowstorms in March, the deer apparently were forced to eat food which they normally do not utilize heavily. Piñon pine, willow, and oak made up a considerable portion of the diet in January and February and contributed lesser amounts in March. Not only the dry leafage of willow, but also the green stems and winter buds, were utilized. The needles of piñon pine and the green and dry leafage of oak made up a substantial part of the January diet. A number of other less important browse species were identified in the stomachs. Forbs and

grasses apparently were not available on the range during the winter of 1951-52. Green grass became available in March, when it was found in 68.8 percent of the stomachs, but it contributed only 0.5 percent to the diet for that month.

In contrast, the food habits of the Inyo mule deer on the Tunawee winter range during the late months of the mild, open winter of 1952-53 are shown in Figure 22. Sagebrush formed the staple item of diet, being found in 100 percent of the stomachs and making up 68.5 percent by volume. Bitterbrush made up 25 percent of the February diet, but contributed virtually nothing to the March and April diets. It is likely that bitterbrush on the Inyo deer ranges follows the same pattern of utilization as in the Devils Garden and Lassen-Washoe winter ranges. The only other relatively important browse forage was California buckwheat, which made up 7.9 and 6.4 percent of the February and March diets and was found in 57.1 percent of the stomachs. Green grass apparently was not abundant on the range, although it was

TABLE 15

Summary of the Food Items Eaten by 21 Inyo Mule Deer Collected from the Tunawee Winter Range in Winter of 1953, Expressed in Percentages

Scientific name	Common name	Number of specimens	February		March		April	
			7		7		7	
			Volume	Frequency	Volume	Frequency	Volume	Frequency
Browse								
Pinus cembroides	Piñon pine		--	--	1.7	28.6	--	--
Ephedra viridis	Green ephedra		0.6	71.4	Trace	42.9	Trace	28.6
Salix sp.	Willow		--	--	Trace	14.3	--	--
Eriogonum fasciculatum	California buckwheat		7.9	57.1	6.4	57.1	0.4	28.6
Atriplex confertifolia	Shadscale		Trace	14.3	Trace	28.6	0.1	28.6
Atriplex canescens	Fourwing saltbush		--	--	0.6	14.3	--	--
Purshia tridentata	Bitterbrush		25.0	57.1	0.7	42.9	Trace	28.6
Prunus andersonii	Desert peach		--	--	Trace	14.3	0.4	14.3
Rhamnus californica	California coffee berry		--	--	Trace	14.3	--	--
Ceanothus greggii	Desert ceanothus		1.6	57.1	0.1	14.3	Trace	14.3
Salvia sp.	Sage		0.1	28.6	--	--	--	--
Chrysothamnus teretifolius	Rabbitbrush		0.1	28.6	0.1	28.6	--	--
Chrysothamnus nauseosus	Rubber rabbitbrush		--	--	--	--	0.4	71.4
Artemisia tridentata	Sagebrush		60.4	100.0	81.4	100.0	63.8	100.0
	Total browse		95.7		91.0		65.1	
Forbs								
Eriogonum sp.	Wild buckwheat		1.4	42.9	Trace	28.6	6.4	71.4
Lupinus sp.	Lupine		0.6	28.6	--	--	17.7	57.1
Erodium circutarium	Red-stem filaree		--	--	--	--	0.3	42.9
Pentstemon sp.	Pentstemon		--	--	Trace	14.3	Trace	14.3
Galium sp.	Bed-straw		--	--	--	--	Trace	28.6
Unidentified forbs			Trace	42.9	Trace	28.6	2.0	85.7
	Total forbs		2.0		--		26.4	
Grass								
Gramineae (green)	Grass family		2.3	71.4	9.0	85.7	7.8	100.0
Gramineae (dry)	Grass family		Trace	42.9	Trace	14.3	0.7	28.6
Bromus sp. (florets)	Brome grass		Trace	14.3	Trace	42.9	Trace	57.1
	Total grass		2.3		9.0		8.5	

high in frequency of occurrence for all three months. It contributed but 9.0 percent to the March, and 7.8 percent to the April diets. In April, however, green forbs began to appear on the range and supplemented the browse diet. Forbs, which contributed practically nothing to the February and March diets, made up 26.4 percent of the April diet.

It is obvious that sagebrush is the staple item of diet for deer inhabiting the southern Inyo winter ranges and also for deer on the northern Inyo ranges. Blackbush, rabbitbrush, piñon pine, oak, and willow apparently are utilized heavily only under severe winter conditions.

With the exception of the 21 stomachs collected from deer on the Tunawee winter range in 1953, the sampling of the Inyo mule deer was conducted during the late winter months of 1951-52 (see climatological data in Figures A-12, A-13, A-14 of the Appendix). This was a critical winter for deer. Heavy snowfall in January forced the deer to move below their normal winter range. Additional storms prevented a return to the better areas of the winter range until the latter part of February. In March, the most severe storms of the winter occurred and culminated in a die-off of deer which had begun in January.

Jones (1954) calculated the winter mortality on the Tunawee to be 40 percent of the herd, with 83 percent of the fawns and 19 percent of the adults succumbing. A comparable loss occurred on the Buttermilk with 41 percent of the herd, composed of 64 percent of the fawns and 23 percent of the adults, dying. Approximately 1,200 of the estimated 3,000 deer on the Buttermilk winter range in December died, as well as 240 of the estimated 600 deer on the Tunawee range.

USE OF WINTER DIE-OFF DEER FOR FOOD HABITS DETERMINATION

The question of the validity of attempting to determine food habits by using samples gathered from deer found dead on the winter range undoubtedly will arise. Of the 272 deer stomach samples analyzed from the Inyo winter deer ranges, 151 represent samples of stomachs of deer found dead as the result of winter die-off. It is significant that dead deer, from which samples were obtained, all had full stomachs, and the percentage composition of the food from these stomachs differed little from that from samples collected by shooting (Table 16).

TABLE 16

Stomach Analysis Comparison of Collected Deer with Winter Die-offs Taken on the Buttermilk Area, Expressed in Percentages

	80 Samples collected deer		59 Samples winter die-off deer	
	Volume	Frequency	Volume	Frequency
Sagebrush	61.8	96.2	55.4	96.6
Blackbush	18.7	73.8	20.3	64.4
Rabbitbrush	0.9	13.8	5.8	42.4
Bitterbrush	5.4	55.0	3.1	25.4

The similarity between the diets of deer apparently surviving the winter and those which succumbed seemingly indicates that the deer which survived did so not because of a better winter diet, but because they possessed greater vigor and condition.

SUMMARY

Inhabiting the sagebrush formation of the Great Basin in California are the Rocky Mountain and Inyo mule deer. A study was made to determine the food habits of these deer, based on analyses of 978 deer stomachs collected from four representative winter deer ranges: Devils Garden, Lassen-Washoe, Verdi, and Inyo.

The sagebrush formation in California occurs chiefly east of the crests of the Cascade Range and the Sierra Nevada from the Oregon border to the southern extremity of Owens Valley. In the Devils Garden area this sagebrush formation is broken into dominant associations of ponderosa pine, bitterbrush, and juniper, which form the vegetative types. To the south, the vegetation is dominated by the sagebrush climax with adaphic associations of bitterbrush, juniper, ponderosa pine, and other subdominants.

The plants which form the bulk of the winter food of Rocky Mountain and Inyo mule deer consist of sagebrush, bitterbrush, juniper, and annual grasses. Sagebrush proved to be the staple item of diet for the deer inhabiting the Lassen-Washoe and Inyo ranges. It constituted the most important single item of food consumed over the critical winter months. Sagebrush and Sierra juniper contributed heavily to the bulk of the diet of the Devils Garden deer. Bitterbrush was utilized seasonally on all deer ranges. It was eaten heavily by deer during the first three months of the winter, but contributed little to the diet during the remainder of the winter. Deer were able to utilize browse species such as snowbrush, greenleaf manzanita, curlleaf mountain mahogany, and squaw carpet, found on the lower edges of the summer ranges, until snow forced them to the winter ranges.

The greatest variable item of diet was grass. It was utilized throughout the winter by the Great Basin deer. In fact, during one mild, open winter green grass was found to have contributed as much as one-half of the winter food of the Devils Garden deer herd. Yearly climatic fluctuations and the weather over any winter period determine not only the availability of green grass but also largely the ultimate carrying capacity of the winter deer ranges. An open winter is characterized by a heavier usage of grass and a more diversified browse diet. Winter mortality is generally negligible. Conversely, a severe winter forces deer to depend more heavily on browse forage.

Winter mortality is related directly to the severity of the weather and its duration. In severe winters, deer are forced to rely on browse species which normally are eaten less extensively. Among these are the following: Sierra juniper on the Devils Garden winter range and blackbush, rabbitbrush, and piñon pine on the southern Inyo winter ranges. It is apparent that deer will utilize whatever food is available and preference becomes secondary to survival in periods of adverse conditions.

Summer range food habits of deer were studied less extensively and the sampling was limited to the Devils Garden and Lassen-Washoe deer herds. Browse made up nearly 55 percent of the diet of the Devils Garden deer herd in the Fremont National Forest in Oregon. Snowbrush constituted the most important single item of food. Forbs contributed nearly 35 percent of the diet, while the consumption of grass was negligible. The summer food habits study of the Lassen-Washoe deer herd revealed that browse made up 80 percent of the diet, of which bitterbrush was the principal item, with snowbrush second in importance. Forbs made up the remainder of the diet and grass was utilized but little.

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APPENDIX

Climatological Data

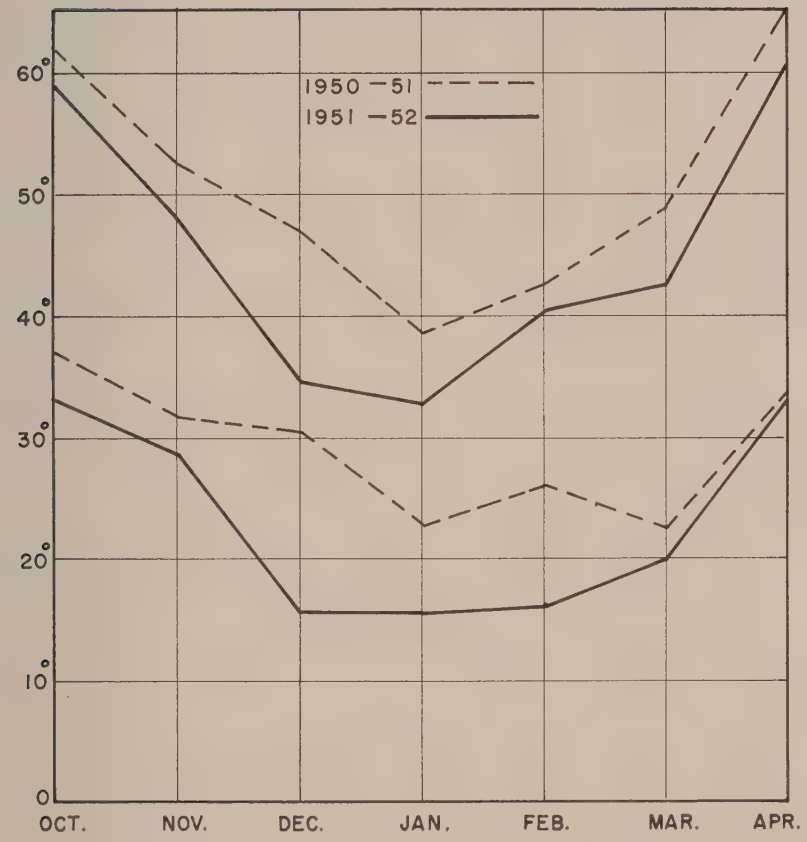

FIGURE A-1. Mean daily maximum and minimum temperatures for Clear Lake Dam, Modoc County.

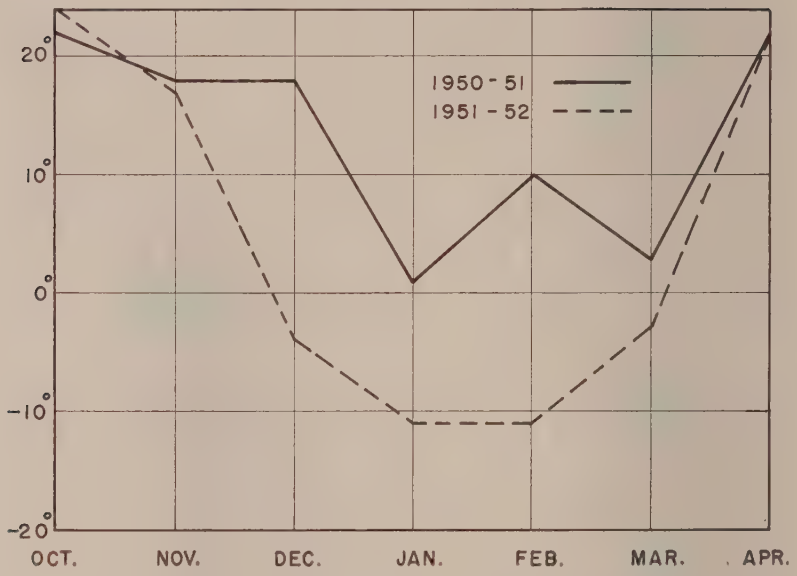

FIGURE A-2. Lowest recorded monthly temperatures for Clear Lake Dam, Modoc County.

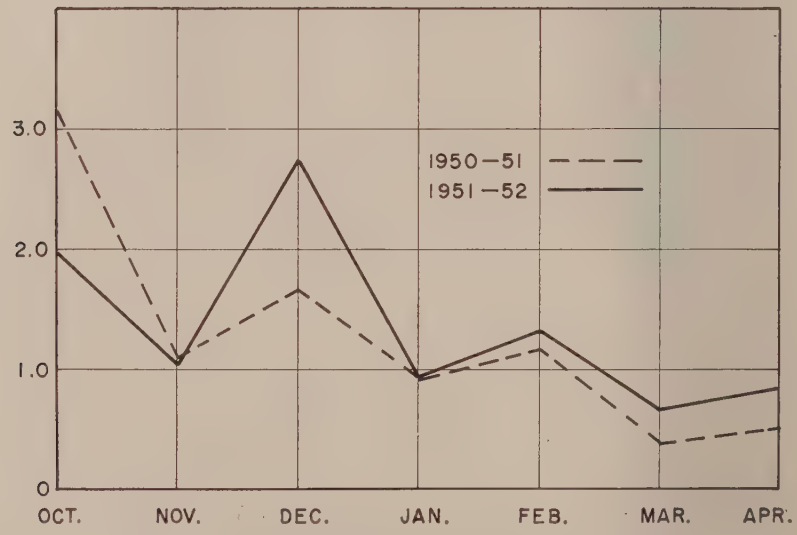

FIGURE A-3. Monthly precipitation for Clear Lake Dam, Modoc County.

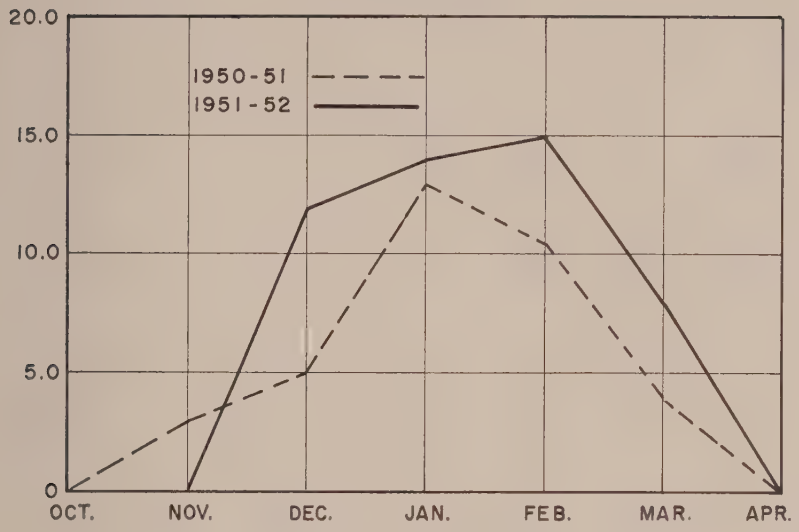

FIGURE A-4. Monthly snowfall for Clear Lake Dam, Modoc County.

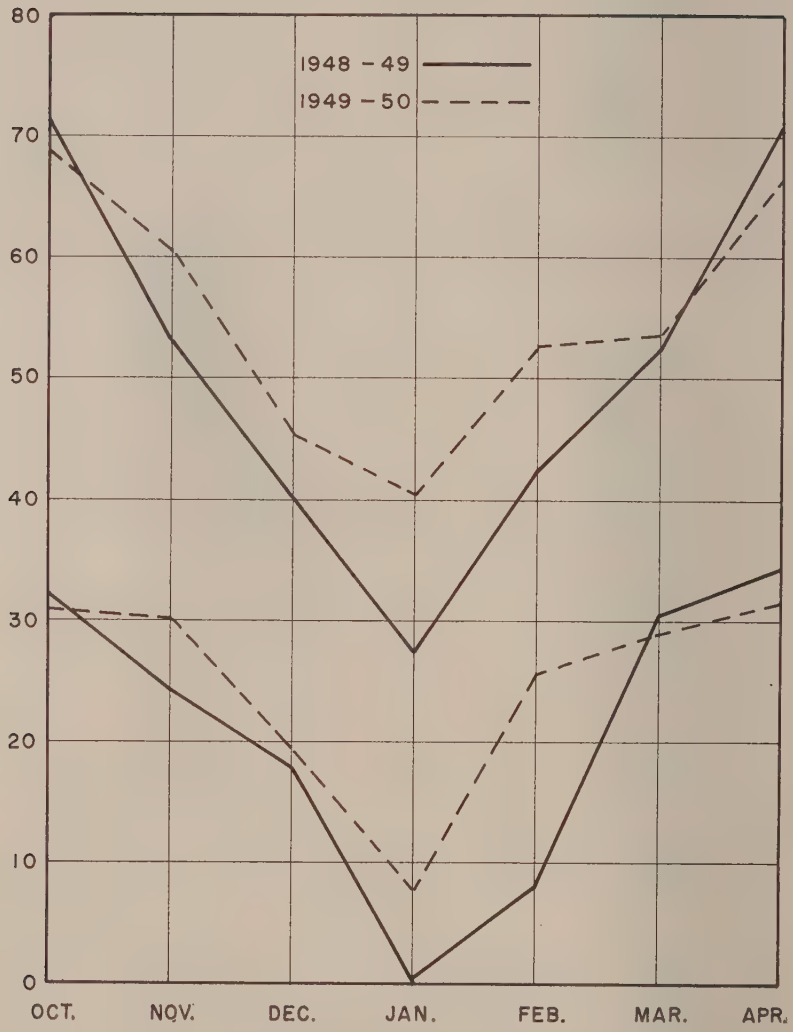

FIGURE A-5. Mean daily maximum and minimum temperatures for Doyle, Lassen County.

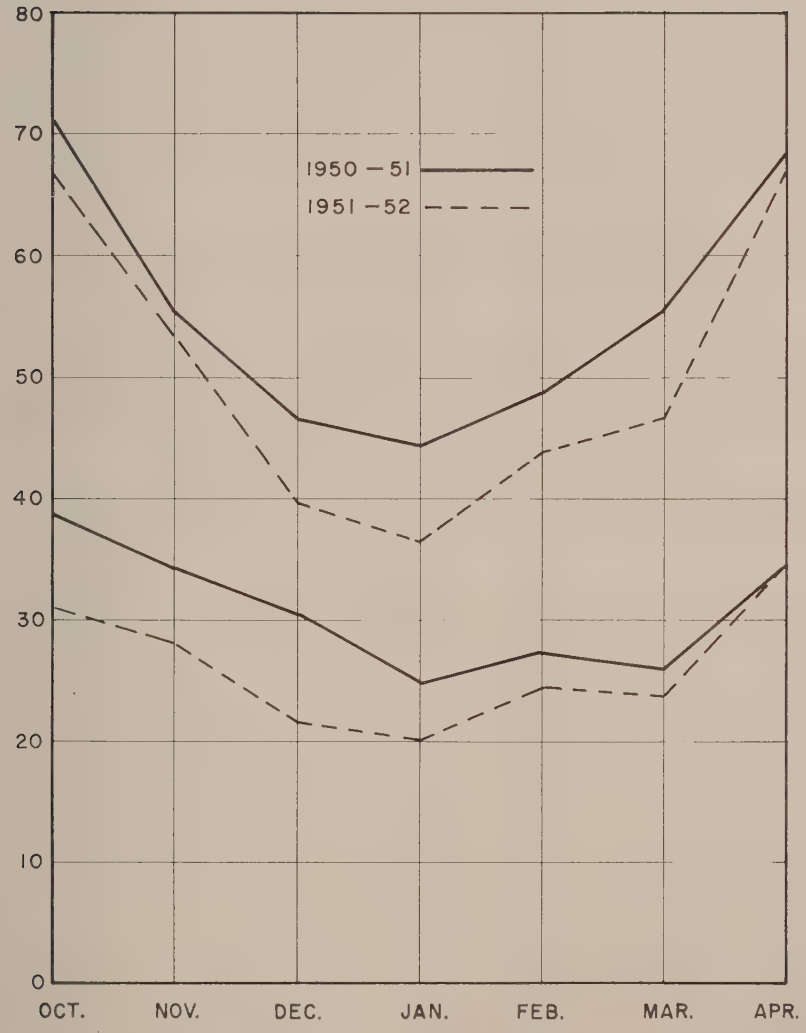

FIGURE A-6. Mean daily maximum and minimum temperatures for Doyle, Lassen County.

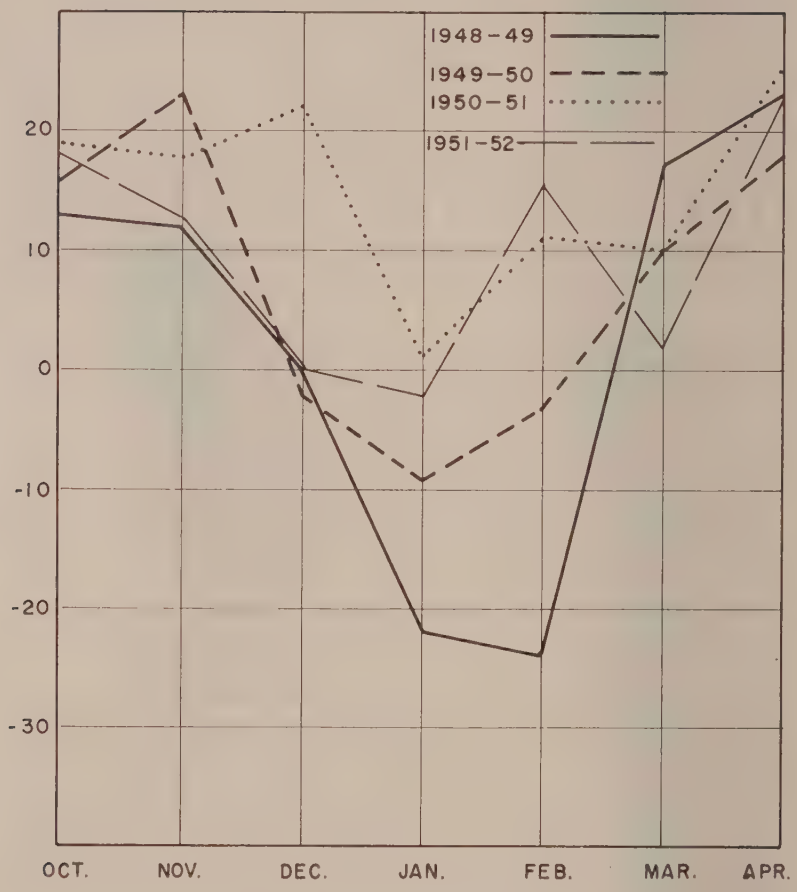

FIGURE A-7. Lowest recorded monthly temperatures for Doyle, Lassen County.

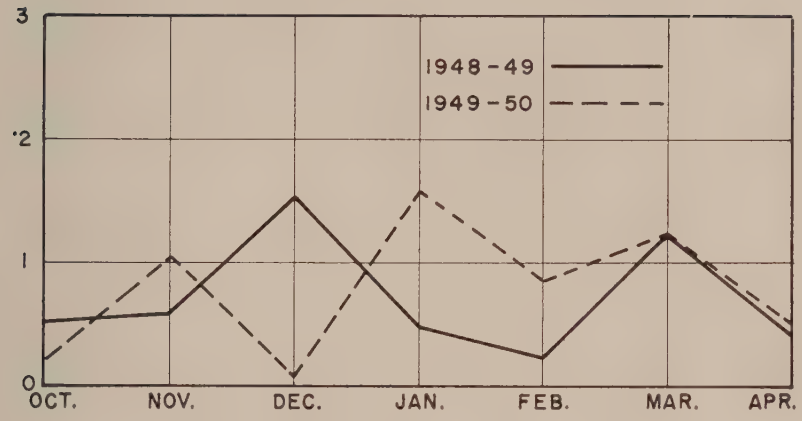

FIGURE A-8. Monthly precipitation for Doyle, Lassen County.

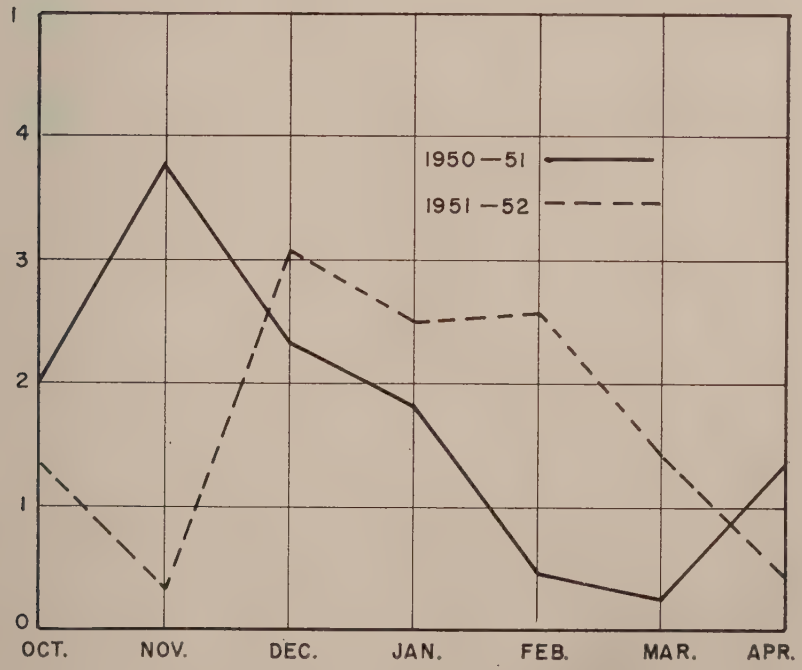

FIGURE A-9. Monthly precipitation for Doyle, Lassen County.

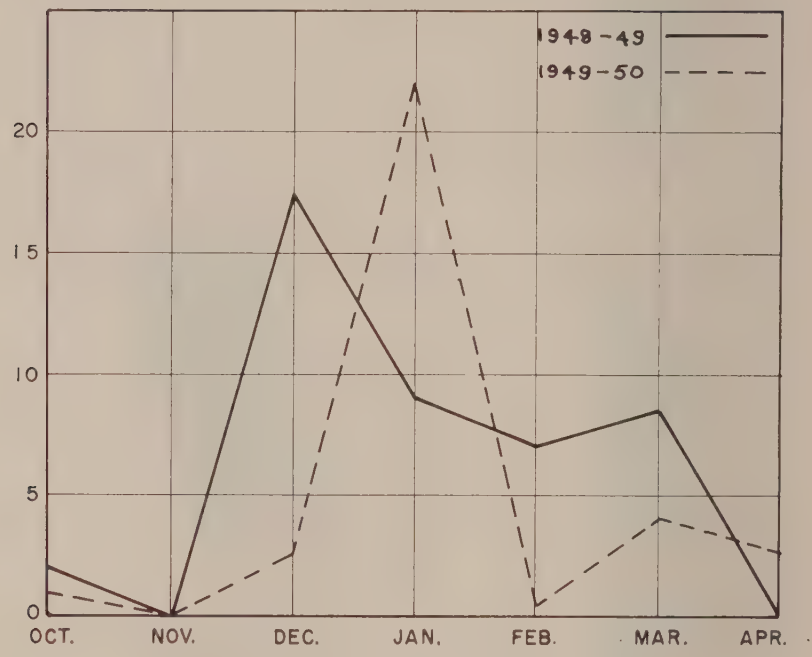

FIGURE A-10. Monthly snowfall for Doyle, Lassen County.

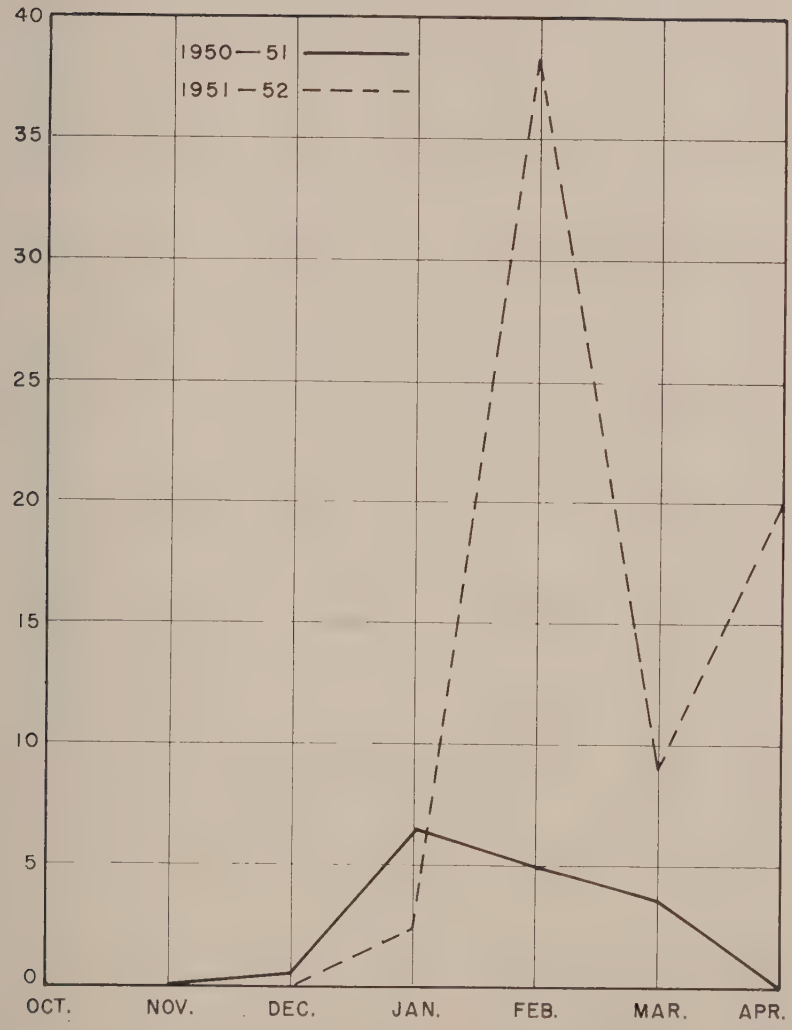

FIGURE A-11. Monthly snowfall for Doyle, Lassen County.

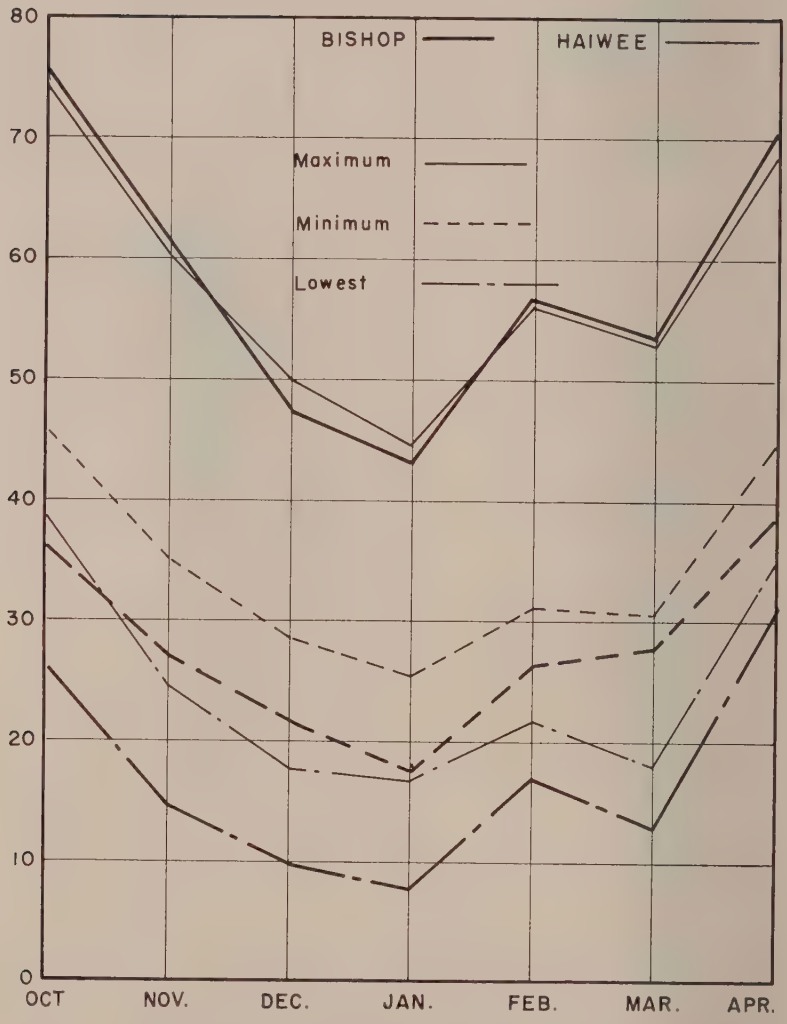

FIGURE A-12. Mean daily maximum and minimum temperatures and lowest recorded monthly temperatures for Bishop and Haiwee, Inyo County. Bishop represents the northern Inyo winter ranges; Haiwee, the southern winter ranges. Winter of 1951-52.

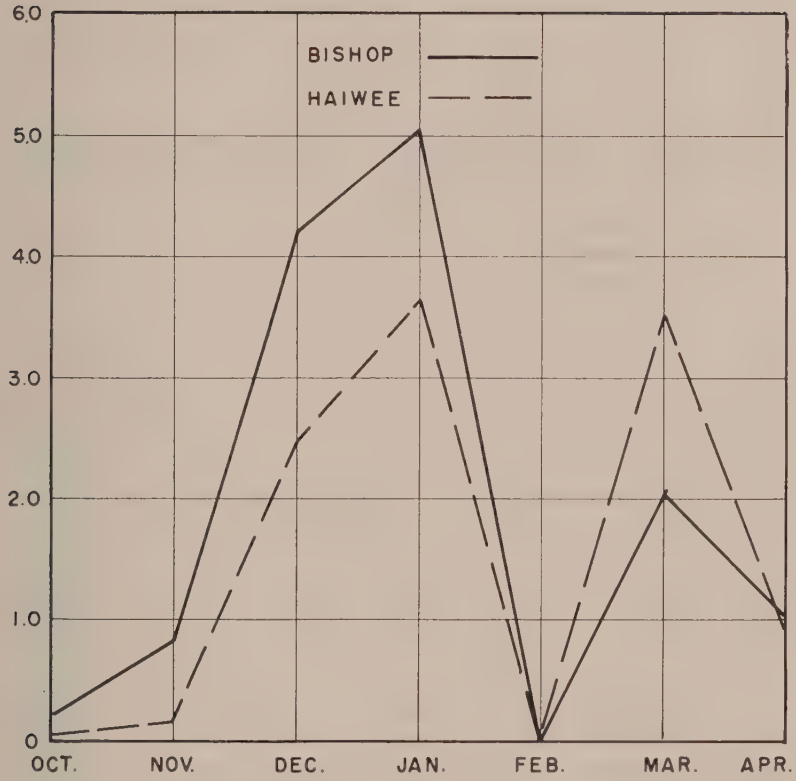

FIGURE A-13. Monthly precipitation for Bishop and Haiwee, Inyo County. Winter of 1951-52.

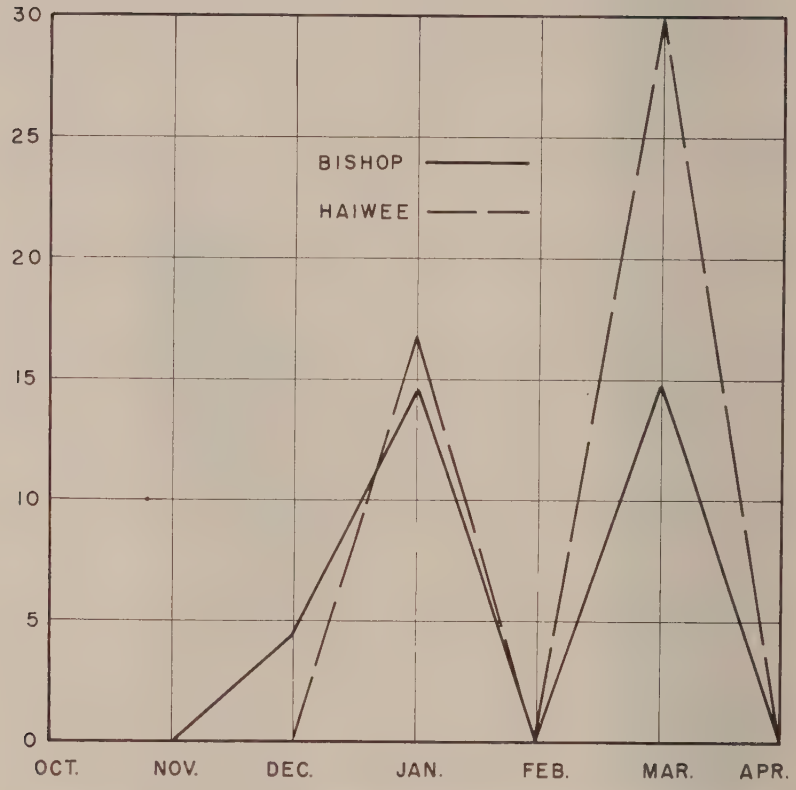

FIGURE A-14. Monthly snowfall for Bishop and Haiwee, Inyo County. Winter of 1951-52.

AVERAGE LUNAR MONTH CATCH OF SARDINE FISHERMEN IN SOUTHERN CALIFORNIA, 1932-33 THROUGH 1954-55[1]

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INTRODUCTION

A measure of the return to the fishermen in terms of the amount of effort expended constitutes one of the important tools available to fisheries biologists and to governmental agencies charged with administering fishery resources. A record of the amount of effort needed, be it in units of gear or units of time, to take a given weight or number of fish furnishes a suitable yardstick to estimate the relative abundance of the fish population on the fishing grounds, and in some instances of the total population also. The use of this tool, however, presupposes a standard unit of effort over a number of years and a demand for fish sufficiently great to assure that the effort expended reflects changing abundance of fish on the grounds and not the changing magnitude of demand.

Neither of these conditions has prevailed continuously throughout the history of the sardine fishery and as a result the problem has been approached several times by somewhat different methods. All workers have conceded that prior to 1932-33 the supply of sardines (*Sardinops caerulea*) on the California fishing grounds was large and the fisherman's catch was determined by the size of the net and the boat and the ability of the processor to use the fish, but not by the abundance of the fish. No estimates are available, therefore, of return per unit of effort for the California sardine fishery prior to 1932-33. Clark (1939) made the first calculations based on the Monterey and San Pedro fisheries for the seasons 1932-33 through 1937-38. Silliman and Clark (1945) refined the methods and applied them to the fisheries out of San Francisco, Monterey, and San Pedro for the seasons 1932-33 through 1941-42. Clark and Daugherty (1950, 1952) continued the studies through 1950-51.

The techniques developed by these workers were satisfactory for the California sardine fishery until 1952-53. During the seasons prior to 1952 the fishery was failing rapidly, especially on the San Francisco and Monterey fishing grounds, but boats still operating were sufficient to yield data on which to base the calculation of return per unit of effort. In 1952-53 and 1953-54 the fishery collapsed and less than 5,000 tons were taken each season from all the California grounds. This failure invalidated any previously applied formulae to determine which

[1] Submitted for publication May, 1956.

boats were actively engaged in fishing. In 1954-55 the southern California fishery revived as a result of an upsurge in availability of sardines on the fishing grounds, but a depressed market prevented the processors from accepting all the fish the fishermen could have supplied.

Consequently, the return per unit of effort did not reflect the true abundance of sardines on the southern California grounds. New methods were necessary, therefore, to carry the measures through the 1952-53 and 1953-54 seasons and to try to determine how much the depressed markets held down the catch of individual fishing boats in 1954-55. The results are presented in this report.

The procedures are bold and they may be unacceptable to some. They do, however, give some indication of the abundance and availability of sardines in California waters, and if interpreted with sufficient caution, should not lead far astray. Since there are still too few sardines in central California waters to permit a fishery out of Monterey or San Francisco, comparison over the years can be made for the southern California fishery only. The present calculations indicate that the yield per unit of effort, either in tons or numbers, was less in 1952-53 and 1953-54 than ever experienced in a prior season. No other result was expected, due to the practically complete failure of the fishery in these two seasons. In 1954-55 fishing was much improved, but the catch per unit of effort was below all other seasons except the two just mentioned and that of 1947-48. The data do not indicate that depressed market conditions materially reduced the catch and suggest, therefore, that although much better than in 1952-53 and 1953-54, this last season did not mark a major upswing in abundance or availability of sardines on the California fishing grounds.

Throughout the past 20 years the southern California season has grown shorter and shorter. In the latter half of the 1930's the fishermen experienced good returns through February. In the first half of the 1940's fishing began to fall off by the end of January and in the last half of the decade by the end of December. During the early 1950's the sharp decline began in November and at present good fishing prevails for only about six weeks during October and November.

The relative size of each year class, measured by the number of sardines taken per boat month when the year class is two and three years old, has been consistently small since 1949 and only four average or better than average groups have appeared on the California fishing grounds since 1941.

METHODS

Unit of Measure

Records of fishermen's catches are compiled in pounds or tons. For the sardine fishery the most convenient unit has been the short ton (2,000 pounds) and is here used. In addition, each season's tonnage has been converted to numbers of fish by average weight figures derived from semiweekly sampling of the catch. This report, as in former studies, gives the return per unit of effort both in tons and in numbers of fish.

Unit of Effort

The poundage of fish delivered by each fisherman is obtained by the Department of Fish and Game from the dealer who buys the fish. Unfortunately, if a boat operates but takes no fish, no record of this effort is made. For the sardine fishery, therefore, it has been necessary to select a time interval as the unit of effort and thus allow for the effect of these zero catches. Most of the catches are made at night after moonset or before moonrise and fishing ceases for several nights during the full moon. As a result, the lunar month, from full moon to full moon, has proved to be a satisfactory unit of effort and has been used in former studies. Night fishing still predominates, despite the introduction of echo-sounding equipment and airplanes to locate fish schools, and the lunar month has been continued in this study. The dates of the lunar months for the six seasons, 1949-50 through 1954-55, are given in Table 1.

TABLE 1

Dates of Lunar Months Used for Comparison of the Catch of Each Boat With its Catch in the Corresponding Lunar Month of the Previous Season

Lunar month	Season		
	1949-50	1950-51	1951-52
"October"	Oct. 7 – Nov. 5	Sept. 27 – Oct. 25	Sept. 16 – Oct. 15
"November"	Nov. 6 – Dec. 4	Oct. 26 – Nov. 24	Oct. 16 – Nov. 13
"December"	Dec. 5 – Jan. 2	Nov. 25 – Dec. 23	Nov. 14 – Dec. 13
"January"	Jan. 3 – Feb. 1	Dec. 24 – Jan. 22	Dec. 14 – Jan. 11

Lunar month	Season		
	1952-53	1953-54	1954-55
"October"	Oct. 4 – Nov. 2	Sept. 23 – Oct. 22	Oct. 12 – Nov. 9
"November"	Nov. 3 – Dec. 1	Oct. 23 – Nov. 20	Nov. 10 – Dec. 9
"December"	Dec. 2-31	Nov. 21 – Dec. 20	Dec. 10 – Jan. 7
"January"	Jan. 1-29	Dec. 21 – Jan. 19	Jan. 8 – Feb. 7

Linkage

Although all sardines are taken in round haul nets, either purse seine or ring net, one of the characteristics of the fleet is a constant change of boats and a continual introduction of new and improved fishing techniques. Because of this, it has not been possible to select an appreciable number of boats which consistently fished over periods as long as 10 years and to compare their fishing success from season to season. To obviate this difficulty all the former studies have resorted to linkage. This involves comparing the fishing success of each boat in season 2 with its success in season 1, obtaining for each season an average measure of success for all boats so compared, and calculating the ratio of season 2 average to season 1 average. A base year is then selected and the ratio of each preceding or succeeding season is used to express its catch in terms of percentage, tons, or numbers of the base year. Each

adjacent season is similarily linked and the chain completed. Linkage has been used in this study and the details of the calculations are evident in Tables 4 and 5. The 1941-42 season, selected by Clark and Daugherty (1952) as a base year, has been used in this report. Average lunar month catch as here given thus represents the success of sardine fishermen in terms of boats of the size and efficiency of those in operation in that season.

Selection of Boats

Fishermen are not successful on every fishing trip and no record is available of the times that a boat puts to sea but catches no fish. It has been necessary, therefore, to draw up rules on which to base a decision as to whether or not a given boat will be considered fishing during the lunar month and whether its catch will be used in the study. In former studies, as a rule, a boat was considered fishing if it fished in comparable lunar months of two successive seasons and made deliveries in two of the four weeks of the lunar month involved.

In 1952-53 and 1953-54 no sardines were found except in southern California. In these waters fish were so scarce that many boats fished throughout a lunar month with only one or two catches of sardines or none at all. New rules had to be established if the calculations were to be carried through this time interval. As the sardine fishing failed, fishermen and processors turned more and more to substitute fish: Pacific mackerel (*Pneumatophorus diego*), jack mackerel (*Trachurus symmetricus*), and anchovies (*Engraulis mordax*). All are caught by the same gear and the fishermen took any one of the three species if sardines, the preferred fish, could not be found. In this study the assumption was made, therefore, that any boat delivering any one of the four species—sardine, Pacific mackerel, jack mackerel, or anchovies—was fishing for sardines. Based on this premise, a boat was considered fishing if it:

1. Landed fish one day out of each of three weeks of a lunar month.
2. Landed fish in the last two lunar weeks but not in the first, provided it fished in the prior lunar month.
3. Landed fish in the first two lunar weeks but not in the last two, provided it fished in the succeeding lunar month.
4. Landed fish in the second and third lunar weeks only, provided it also landed fish in the prior or succeeding lunar month.
5. Landed fish in the first and fourth, the first and third, or the second and fourth lunar week.
6. Landed fish in only one week of a lunar month, provided it landed fish in both the prior and succeeding lunar month.

If a boat landed fish in the first two, middle two, or last two weeks of a lunar month but did not land fish in the prior or succeeding lunar month, it was considered as fishing one half of a month.

At the beginning and end of the sardine season the performance of a boat was checked against its fishing activity for the two mackerels and for anchovies in the month preceding or following the sardine season.

When a season opened after the beginning of a lunar month, the data for that month were treated as a fraction of the time interval, one-half or three-fourths of a month. When strikes interfered with fishing, fractions of months were similarily treated.

Calculations under the former rules had been carried out through the 1951-52 seasons. To determine how greatly the above criteria for selecting boats might affect the results, the new procedure was carried through for the 1949-50, 1950-51, and 1951-52 seasons. Thus, the ratios for the two pairs of years resulting from the former and the present methods can be compared (Table 2). For both pairs the new method gives a somewhat greater ratio than the former. In 1950-51 the increase is 12.5 percent and in 1951-52, 9.1. These differences were not considered of sufficient magnitude to invalidate the use of the present method to determine whether a boat was fishing throughout a lunar month and the new caluculations were linked with the former without the use of any adjustment factor. All figures in this study for 1950-51 and following seasons are based on the new rules.

TABLE 2

Comparison of Present Method with Former Method for Selection of Fishing Boats

Season	Former method average monthly catch		Present method average monthly catch		Difference in percentage
	Tons	Ratio	Tons	Ratio	
1949-50	386.0	--	336.4	--	--
1950-51	291.2	0.7544	285.6	0.8490	+12.5
1950-51	315.5	--	273.6	--	--
1951-52	153.6	0.4868	145.3	0.5311	+9.1

In former studies it was possible to use 50 to 80 percent of the total boats fishing in each season and 40 to 80 percent of the total tons landed. The present analyses have included 40 to 80 percent of the boats and 30 to 80 percent of the total tonnage (Table 3).

TABLE 3

Number of Boats Used in the Calculation of the Average Lunar Month Catch for Southern California Compared with the Total Number of Boats Fishing in Southern California

Seasons compared	Number of boats			Number of tons		
	Used in the analysis	Total fishing	Percentage of total	Used in the analysis	Total landed	Percentage of total
1949-50	196	257	76	147,086	188,168	78
1950-51	196	319	61	127,935	305,745	42
1950-51	271	319	85	208,870	305,745	68
1951-52	271	335	81	96,835	111,411	87
1951-52	167	335	50	51,360	111,411	46
1952-53	167	204	82	3,274	4,476	73
1952-53	84	204	41	1,532	4,476	34
1953-54	84	154	55	1,530	3,172	48
1953-54	100	154	65	2,087	3,172	66
1954-55	100	176	57	27,386	66,428	41

AVERAGE LUNAR MONTH CATCH

In previous reports, average catches derived from sardine landings in Los Angeles and San Diego harbors have been credited to San Pedro. In the more recent years a higher percentage of the tonnage has been delivered to the port of Hueneme. Boats operating out of this port and out of Los Angeles Harbor fish throughout southern California waters and the more general term southern California is here used to describe the landings at all ports from Santa Barbara south to San Diego.

The average lunar month catch reached an all-time low in 1952-53 and 1953-54 (Figure 1, Tables 4 and 5). The revival of the 1954-55 southern California fishery and resultant increase in average lunar month catch needs further clarification.

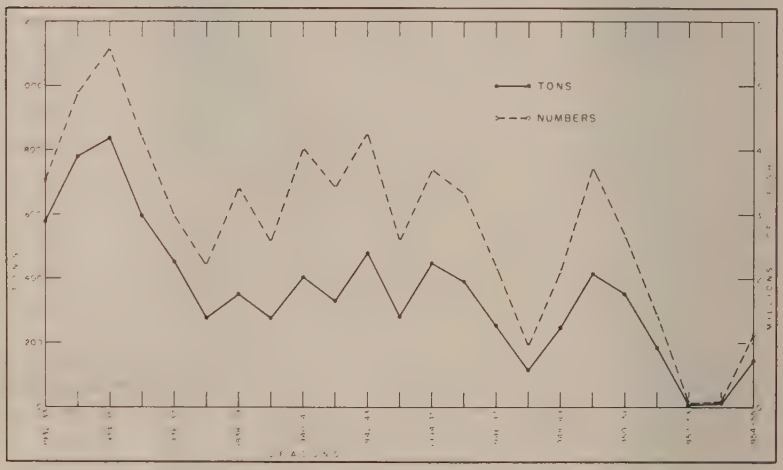

FIGURE 1. Average catch per lunar month in tons and in numbers for sardines on the southern California fishing grounds. Base year, 1941-42.

Figure 1 and Tables 4 and 5 contain no adjustment for the effect of a depressed market, which during the first few weeks of the 1954-55 season prevented the fishermen from bringing in all the fish they could have caught in a night's fishing. To compensate for this, frequently a crew would call another boat by radio-telephone and load part of its catch onto the second boat, which had been less successful on the particular night. This tended to compensate for the limitations placed on the boats by the processors and mitigated to a measure the effects of the depressed market. By December, the level of abundance of fish on the southern California fishing grounds had declined to the point where the processors could absorb all fish that were landed and limitations were no longer placed on the tonnages delivered by individual boats.

TABLE 4

Average Lunar Month Catch in Tons for Southern California

Season	Average monthly catch		Linkage (average monthly catch)		Total catch tons	Total boat months
	Tons	Ratio	Tons	Percentage		
1932-33	335.3	0.7407	578.4	174.26	83,492	144.3
1933-34	452.7					
1933-34	420.1	0.9317	780.9	235.27	126,438	161.9
1934-35	450.9					
1934-35	404.3	1.4117	838.1	252.52	183,614	219.1
1935-36	286.4					
1935-36	356.5	1.3131	593.7	178.88	148,822	250.7
1936-37	271.5					
1936-37	281.8	1.6298	452.1	136.23	142,483	315.2
1937-38	172.9					
1937-38	182.3	0.7875	277.4	83.59	109,122	393.4
1938-39	231.5					
1938-39	251.1	1.2720	352.3	106.15	148,125	420.5
1939-40	197.4					
1939-40	210.2	0.6834	277.0	83.45	93,176	336.4
1940-41	307.6					
1940-41	383.8	1.2211	405.3	122.11	171,747	423.8
1941-42	314.3					
1941-42	331.9		331.9	100.00	147,825	445.4
1942-43	479.5	1.4447	479.5	144.47	202,597	422.5
1942-43	541.4					
1943-44	318.0	0.5874	281.7	84.86	135,007	479.3
1943-44	308.1					
1944-45	490.3	1.5914	448.3	135.05	177,465	395.9
1944-45	509.3					
1945-46	446.3	0.8763	392.8	118.34	170,325	433.6
1945-46	434.5					
1946-47	283.3	0.6520	256.1	77.16	197,830	772.5
1946-47	297.5					
1947-48	134.2	0.4511	115.5	34.81	95,314	825.2
1947-48	131.0					
1948-49	279.4	2.1328	246.3	74.24	117,321	476.3
1948-49	240.9					
1949-50	406.6	1.6878	415.7	125.30	188,168	452.7
1949-50	336.4					
1950-51	285.6	0.8490	352.9	106.38	305,745	866.4
1950-51	273.6					
1951-52	145.3	0.5311	187.4	56.50	111,411	594.5
1951-52	206.7					
1952-53	10.6	0.0513	9.6	2.90	4,471	465.7
1952-53	10.7					
1953-54	11.9	1.1121	10.7	3.23	3,172	296.4
1953-54	12.9					
1954-55	175.0	13.5659	145.2	43.82	66,428	457.5

TABLE 5

Average Lunar Month Catch in Numbers for Southern California

Season	Average monthly catch		Linkage (average monthly catch)		Total catch numbers	Total boat months
	Numbers	Ratio	Numbers	Percentage		
1932-33	2,044,512	0.7226	3,526,725	103.06	509,097,600	144.4
1933-34	2,829,375					
1933-34	2,625,625	0.8735	4,880,605	142.63	789,776,500	161.8
1934-35	3,006,000					
1934-35	2,695,333	1.3270	5,587,413	163.29	1,224,708,700	219.2
1935-36	2,031,206					
1935-36	2,528,369	1.4155	4,210,560	123.05	1,053,331,100	250.2
1936-37	1,786,184					
1936-37	1,853,947	1.3511	2,974,610	86.93	936,642,300	314.9
1937-38	1,372,222					
1937-38	1,446,825	0.6437	2,201,621	64.34	866,906,000	393.8
1938-39	2,247,573					
1938-39	2,437,864	1.3338	3,420,259	99.95	1,437,404,800	420.3
1939-40	1,827,778					
1939-40	1,946,296	0.6327	2,564,297	74.94	862,740,700	336.4
1940-41	3,076,000					
1940-41	3,838,000	1.1845	4,052,943	118.45	1,712,317,900	422.5
1941-42	3,240,206					
1941-42	3,421,649		3,421,649	100.00	1,524,396,400	445.5
1942-43	4,523,585	1.3220	4,523,420	132.20	1,919,972,000	424.5
1942-43	5,107,547					
1943-44	2,917,431	0.5712	2,583,778	75.51	1,241,122,700	480.4
1943-44	2,826,606					
1944-45	4,052,066	1.4335	3,703,846	108.24	1,465,636,300	395.7
1944-45	4,208,264					
1945-46	3,782,203	0.8988	3,329,017	97.29	1,444,233,900	433.8
1945-46	3,682,203					
1946-47	2,421,368	0.6576	2,189,162	63.98	1,688,147,800	771.1
1946-47	2,542,735					
1947-48	1,118,333	0.4398	962,793	28.14	792,379,900	823.0
1947-48	1,091,667					
1948-49	2,388,034	2.1875	2,106,110	61.56	1,003,782,326	476.6
1948-49	2,058,974					
1949-50	3,663,063	1.7791	3,746,980	109.52	1,698,032,000	453.2
1949-50	3,030,631					
1950-51	2,163,636	0.7139	2,674,969	78.19	2,318,938,000	866.9
1950-51	2,072,727					
1951-52	1,117,692	0.5392	1,442,343	42.16	854,836,760	592.7
1951-52	1,589,846					
1952-53	55,312	0.0348	50,194	1.47	23,334,963	464.9
1952-53	55,625					
1953-54	74,654	1.3421	67,365	1.97	19,924,607	295.8
1953-54	81,384					
1954-55	1,377,874	16.9305	1,140,523	33.35	521,859,651	457.6

A similar decline within the season in average lunar month catch has occurred throughout the history of the southern California sardine fishery. Throughout the succeeding seasons since 1940, its onset has started earlier and earlier. This trend has been reflected in the legislation governing the length of the legal season. In the 1930's the southern California season opened November 1 and closed at the end of March. Within 10 years, fishing in March had become poor and the industry requested a closure in March and an opening on the first of October. Such a law was enacted in 1941. Fishing continued to decline, however, especially in February. In 1949, the season was shortened by another month and closed on February 1.

TABLE 6

Average Catch for the Southern California Fishery, in Thousands of Pounds per Lunar Month Within the Season

Season	Lunar month						Number of boats used
	"October"	"November"	"December"	"January"	"February"	"March"	
1934-35		1,062.2	796.7	989.0	1,294.5	730.7	37
1935-36		703.8	323.6	798.3	1,048.1	710.2	22
1936-37		437.6	515.0	439.0	268.6	374.5	27
1938-39		732.8	532.8	435.1	485.7	308.7	42
1939-40		438.5	646.3	489.3	323.7	279.2	35
5-season average		675.0	562.9	630.1	684.1	480.7	
Percentage of November		100.0	83.4	93.3	101.3	71.2	
1940-41	1,381.4	1,302.4	372.8	720.9	329.5		30
1941-42	1,331.3	570.4	603.7	630.5	619.8		21
1942-43	1,553.8	1,424.1	1,322.6	858.1	452.8		33
1943-44	1,010.5	743.0	765.4	890.9	340.8		16
1944-45	1,669.1	776.2	1,127.6	672.9	557.0		22
5-season average	1,389.2	963.2	838.4	754.7	460.0		
Percentage of November	144.2	100.0	87.0	78.4	47.8		
1945-46	1,410.9	940.0	1,155.9	449.8	659.1		20
1946-47	1,248.8	553.9	344.4	182.9	382.9		16
1948-49	1,368.7	448.2	470.6	231.4			66
1950-51	975.2	720.0	607.7	352.4			82
4-season average	1,250.9	665.5	644.6	304.1			
Percentage of November	188.0	100.0	96.9	45.7			
1951-52	986.2	343.2	118.5	101.6			82
1954-55	363.3	137.8	39.2	12.5			32
2-season average	674.8	240.5	78.8	57.0			
Percentage of November	280.6	100.0	32.8	23.7			

Within any given season the month by month average catch varied considerably, but five-season averages smooth out such variations and give a clearer picture of the within-season changes which have taken place in the availability of sardines on the southern California fishing grounds (Figure 2, Table 6). Due to strikes, the data for 1937-38 and 1947-48 were not usable and have been omitted in these calculations

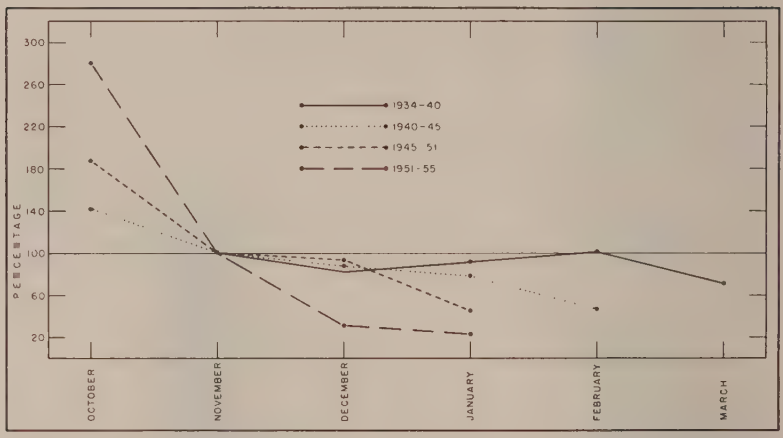

FIGURE 2. Changes within the southern California season in the average lunar month catch for five-, four-, and two-season periods. All monthly averages expressed in percentage of November.

of within-season monthly averages. To bring all averages to a common level, each is expressed in percentage of the November average catch. After the legal opening of October to fishing, all seasons showed the greatest fishing success in this lunar month. In the last half of the 1930's, the average lunar month catch was at a relatively constant level between November and February. In the first half of the 1940's the average lunar month catch declined by February and in the last half of the 1940's by December. Too few fish were available to permit any analyses in 1952-53 and 1953-54. In 1951-52 and 1954-55 there was a sharp and continuing decline from October to December.

As stated previously, economic conditions were unfavorable at the beginning of the 1954-55 season. This tended to prevent the landing of as great a tonnage of sardines as the fishermen were able to take, and presumably resulted in a smaller average lunar month catch than would have occurred if the abundance of fish on the grounds had been the only factor influencing this average. During November the abundance declined and by December it reached the point where the market could absorb all the tonnage the fishermen could catch and the abundance determined the size of the average lunar month catch. The unfavorable economic conditions tended, therefore, to produce a lower monthly average in October, 1954, than would have occurred with more favorable markets, and the decline in the average from October to November was less than it would have been under normal circumstances. A comparison of this rate of decline between October and November with the rate between the same two lunar months in 1951 should give a measure of the amount that economic conditions curtailed the 1954-55 catch. There was actually little difference between the two seasons. October average exceeded November average by 287 percent in 1951-52 and by 264 percent in 1954-55, the former being 1.09 times the latter. This may be merely the result of sampling errors or it may reflect economic conditions. If the latter, it could be concluded that, had there not been a depressed market, the average catch

per lunar month in 1954-55 would have been 1.09 times greater than the calculations indicate, 158.3 tons instead of 145.2. This suggests that the unfavorable economic conditions had only a small effect on the measures of return per unit of effort and that the southern California fishermen have experienced, in the history of the fishery, only three other seasons in which fishing success was poorer than in 1954-55. These were 1947-48, 1952-53, and 1953-54.

MEASURES OF THE STRENGTH OF YEAR CLASSES

One of the tools obtained from a study of return per unit of effort is an estimate of the number of units required to make a season's catch. For the sardine fishery this is expressed in numbers of boat months (Tables 4 and 5, last column). By dividing the number of fish of a given year class caught in a season by the number of boat months operating within the season, the relative strength of the year class is obtained at a specific age. This has been done previously by Clark and Daugherty (1952), Felin (1954), and Eckles (1954). The present study brings these measures up to date.

TABLE 7

Relative Strength of Individual Year Classes Measured by the Number Taken per Boat Month at Monterey and in Southern California When Approximately 2½ and 3½ Years Old. Numbers in Thousands (i.e., 000's omitted).

Year class	Number per boat month				Av. no. per boat month*
	At 2½ years		At 3½ years		
	Monterey	So. Calif.	Monterey	So. Calif.	
1929	--	--	996.2	1,514.6	1,267.9
1930	273.9	246.1	585.0	--	405.6
1931	627.2	808.3	2,240.3	1,679.2	1,371.0
1932	1,516.1	1,324.8	2,015.8	2,307.1	1,815.1
1933	641.0	702.1	1,099.0	--	818.8
1934	720.6	--	353.9	358.0	447.7
1935	754.0	883.9	--	--	819.6
1936	--	--	--	--	--
1937	--	--	--	--	--
1938	--	--	1,178.2	1,043.1	1,111.1
1939	3,240.0	1,766.3	1,957.1	1,582.8	2,158.4
1940	747.6	539.5	1,067.8	728.4	761.7
1941	283.5	966.4	379.5	1,317.5	742.3
1942	1,561.0	1,149.2	686.1	852.3	1,056.8
1943	552.8	1,217.9	83.7	414.6	548.2
1944	53.4	623.8	26.4	187.4	277.0
1945	78.8	326.8	10.9	307.3	219.9
1946	96.2	1,411.0	651.6	1,186.8	915.5
1947	2,156.8	1,554.5	214.8	998.3	1,151.5
1948	10.2	1,231.6	163.6	1,001.0	833.0
1949	19.4	73.5	--	6.0	38.9
1950	--	0.9	--	12.3	5.3
1951	--	1.7	--	418.0	254.6
1952	--	376.9	--	--	376.9

* The average number per boat month represents an average weighted by all fish of a given year class taken when 2½ and when 3½ years at Monterey and in southern California divided by the sum of all boat months in both localities required to take the total number in the two seasons involved.

Data are available for the sardine for a number of different year classes when each was approximately $2\frac{1}{2}$ and $3\frac{1}{2}$ years old. The numbers of fish taken were derived from Felin et al. (1948, 1949, 1950, 1951, 1952, 1953, 1954, 1955), Mosher et al. (1949), and Eckles (1954), and the number of boat months from Clark and Daugherty (1952) and Table 5 of this publication. From these figures, using the Monterey and southern California fisheries, either two or four values for the average lunar month catch have been derived for year classes, 1929-1935 and 1938-1952 (Table 7). Although there are variations between ports and between age groups, all averages indicate that the strong year classes were 1929, 1931, 1932, 1938, 1939, and 1947. Of the remainder, some were better than average, others below average, and 1949 and 1950 extremely weak.

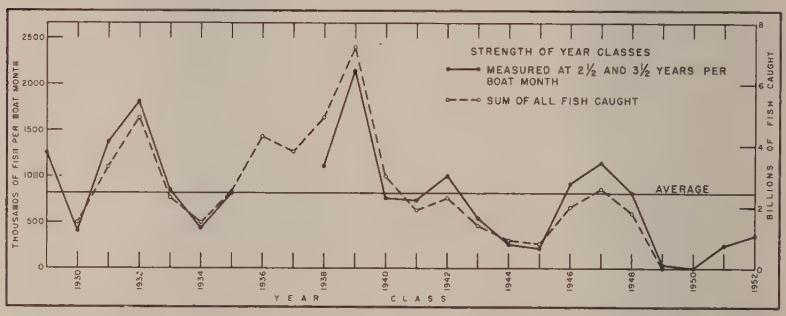

FIGURE 3. Relative strength of sardine year classes as measured (a) when 2½ and 3½ years old and (b) by Clark and Marr (1955) as a cumulative total of all sardines taken in the fishery.

The two or four estimates for a given year class were combined into one average lunar month catch by summing all fish taken at Monterey and in southern California when $2\frac{1}{2}$ and $3\frac{1}{2}$ years old, and dividing this sum by the total number of boat months in each locality in both seasons. The resulting values (Figure 3; Table 7, last column) indicate that year classes have comprised fewer fish since the early 1940's than in the 1930's. The average for the 22 classes was 791 thousand fish per boat month. Clark and Marr (1955) estimated the size of year classes by summing all fish caught from each year class during the time that such a class was taken by the fishery. These values averaged 2.5 billion fish per year class. The two measures are comparable except for the 1946 and subsequent classes. The present study estimates these to be stronger than did Clark's and Marr's estimates. The differences result in part because Clark and Marr terminated their sums with 1952-53, before 1946 and younger fish had run out their life course. More have been taken in later seasons. Because of the low level of availability of sardines on the southern California fishing grounds in 1952-53 and 1953-54, the present measures of the strength of the 1949 and 1950 year classes are also probably too low. These classes have not made a material contribution to the fishery in the following seasons, however, and it seems probable that the estimates are not in serious error.

Both the present measure and that of Clark and Marr indicate that year classes produced during the 1940's and the early 1950's have been appreciably smaller in numbers than in the 1930's. The present study also shows that in general for classes 1929 through 1942 more fish of a given class were taken per boat month at $3\frac{1}{2}$ years than at $2\frac{1}{2}$ years, and for the later groups the reverse was true.

SUMMARY

By developing new rules for determining which boats were fishing for sardines each season, the return to the southern California fishermen per lunar month has been carried through 1954-55.

After almost complete collapse in 1952-53 and 1953-54, fishing in 1954-55 was more successful. In this season, however, the average monthly catch was still less than in any previous season except 1947-48 and the two mentioned above.

Based on the total boat months calculated to be required to make each season's catch, the relative strength was measured for 22 year classes occurring in the fishery between 1932-33 and 1954-55. In the 1930's only two year classes were of less than average strength, while in the 1940's and 1950's nine were below average and only four were above.

During 18 seasons the within-season average monthly catch in southern California showed an increasing decline year by year. In the 1930's fishing success held up through February, in the early 1940's only through January, in the late 1940's only through December, and in the early 1950's only through November.

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A TAGGING EXPERIMENT WITH CHANNEL CATFISH (*ICTALURUS PUNCTATUS*) IN THE LOWER COLORADO RIVER[1]

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The catfish fishery of the lower Colorado River is of vital importance to California's anglers, particularly in heavily-populated southern California, where there are relatively few fishing waters. It is estimated that the fishery provided a catch of 750,000 catfish to California's sport fishermen in 1953. This represented about 10 percent of the total State catfish catch and about 60 percent of the catch in southern California that year.

The channel catfish (*Ictalurus punctatus*) is the most abundant species of catfish in the Colorado River. Dill (1944) expressed the opinion that the catch of channel catfish exceeded that of any other game fish in both numbers and pounds. The yellow bullhead (*Ameiurus natalis*) and black bullhead (*A. melas*) also have been reported from the lower Colorado River. Their role in the fishery, however, apparently is of no significance.

Aside from some general data presented by Dill (*op. cit.*), virtually no information upon which to base effective management of the fishery is available.

This report presents the results of an exploratory tagging study begun in 1953 to provide information on the annual rate of harvest and movements of channel catfish. Data on tagging techniques and efficient methods of trapping channel catfish also were sought.

PROCEDURE

General

The section of river between Parker and Imperial dams was selected for the study (Figure 1). Largemouth bass (*Micropterus salmoides*) are abundant in the area; however, the fishery is dominated by channel catfish. The length of this section is 148 miles.

Headgate Rock Dam is located about 15 miles downstream from Parker Dam, and the Palo Verde Weir lies about 12 miles upstream from Blythe. Both structures are irrigation diversions and apparent barriers to the upstream migration of catfish.

Work began in December, 1953, when 44 fish were tagged and released at Locations A, B, and C, as shown in Figure 1. It was necessary to postpone further tagging operations until April, 1954, because it

[1] Submitted for publication June, 1956. This work was performed as part of Dingell-Johnson Project California F-2-R, "A Study of the Catfish Fishery of California", supported by Federal Aid to Fish Restoration funds.

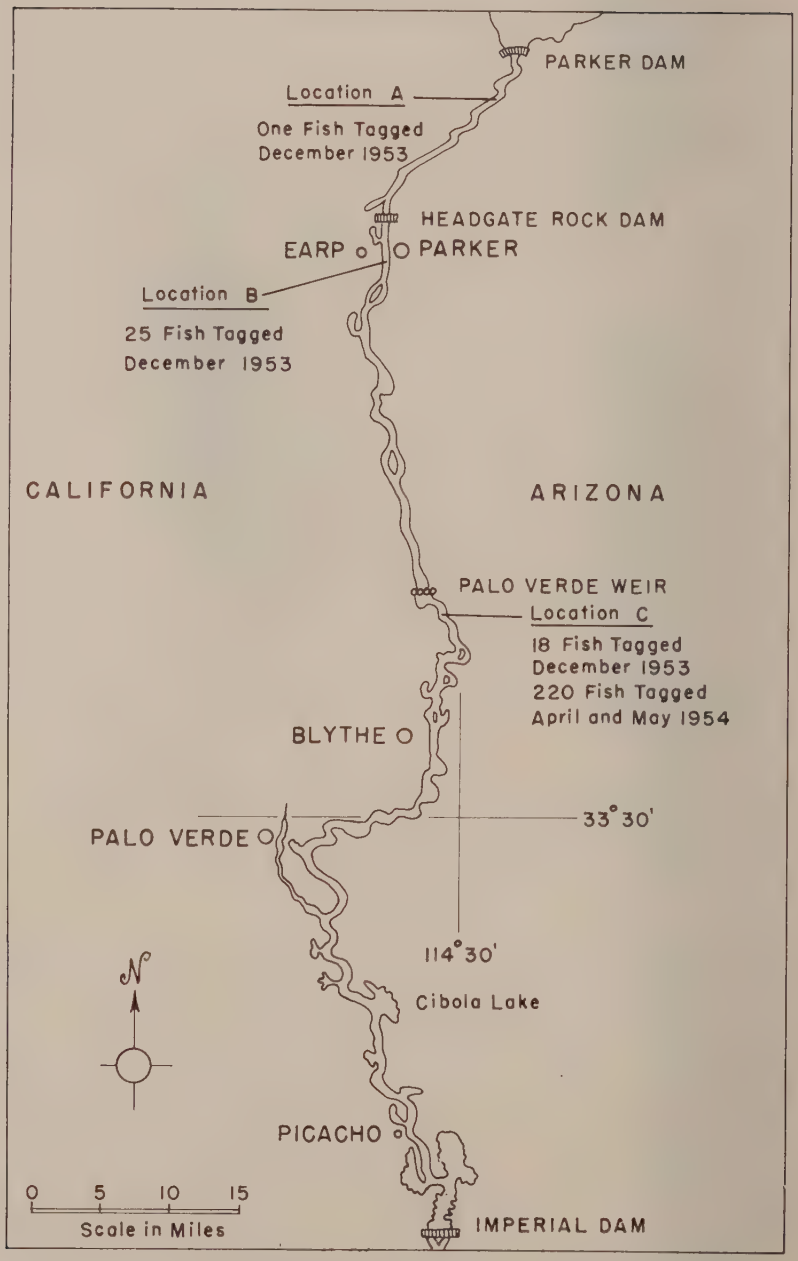

FIGURE 1. Map of the study area, showing locations at which channel catfish were tagged and released.

was not possible to net channel catfish in sufficient numbers during the winter months. In April and May, 1954, 220 fish were tagged at Location C. Thus, the total number of fish tagged was 264.

The fork length of each fish was measured to the nearest tenth of an inch. No fish less than 7.0 inches in length were tagged.

A minimum length was established for two reasons. First, it was believed that the effect of the tag might be harmful to small fish; and second, there was evidence that fish less than 7.0 inches were too small to be caught with the heavy angling gear ordinarily used on the river.

The sex of 160 fish was determined by examination of the genital opening. All determinations of sex were made from fish tagged in April and May, 1954, when the fish were approaching a ripe condition and the sexes were relatively easy to separate. Of 160 apparently mature fish, 91 were females and 69 were males. It is doubtful that this ratio is representative of the entire population.

Trapping Methods

Fyke nets, described by Pelgen and McCammon (1955), were used to capture the fish. This type of net has proven to be highly efficient in taking white catfish (*Ictalurus catus*) and bullheads in other California waters.

During December, 1953, the nets were fished in a variety of locations at several points on the river, but only 44 channel catfish over 7.0 inches in length were taken in 170 net-days. It was thought that low water temperatures (around 52°F.) were primarily responsible for the poor catch. Dill (*op. cit.*) observed that netting in the lower Colorado River was least productive during the early months of cold water.

A second attempt to trap fish was made between April 25 and May 6, 1954. All trapping was confined to an area about two miles downstream from the Palo Verde Weir (Location C, Figure 1). The nets were set in locations that possessed diverse physical characteristics, to determine the effect of net location on trapping efficiency. All positions of individual nets are shown in Figure 2.

Despite water temperatures that ranged between 70 and 75 degrees F., the initial 72 net-days of trapping yielded only 69 fish large enough to tag. Each net was raised every 48 hours during this period. The nets were baited with cottonseed meal pellets in an effort to attract fish into them; however, the catfish catch was not increased. The use of bait did increase the catch of carp (*Cyprinus carpio*) significantly.

The initial failure to catch fish in sufficient numbers resulted in considerable shifting of the net locations, in the hope that more productive sets could be found. By chance, a very successful location was discovered immediately. This set was located just downstream from a sandbar that had been formed on the inside of a meander bend of the river, and was characterized by relatively deep, quiet water. Two additional sandbars were located within the trapping area and nets were placed below them also. This action resulted in an immediate and substantial increase in the catch. In 27 net-days, 151 taggable channel catfish were taken. Several hundred catfish below the minimum tagging length of 7.0 inches were captured also. During this period, the nets were checked every 12 hours.

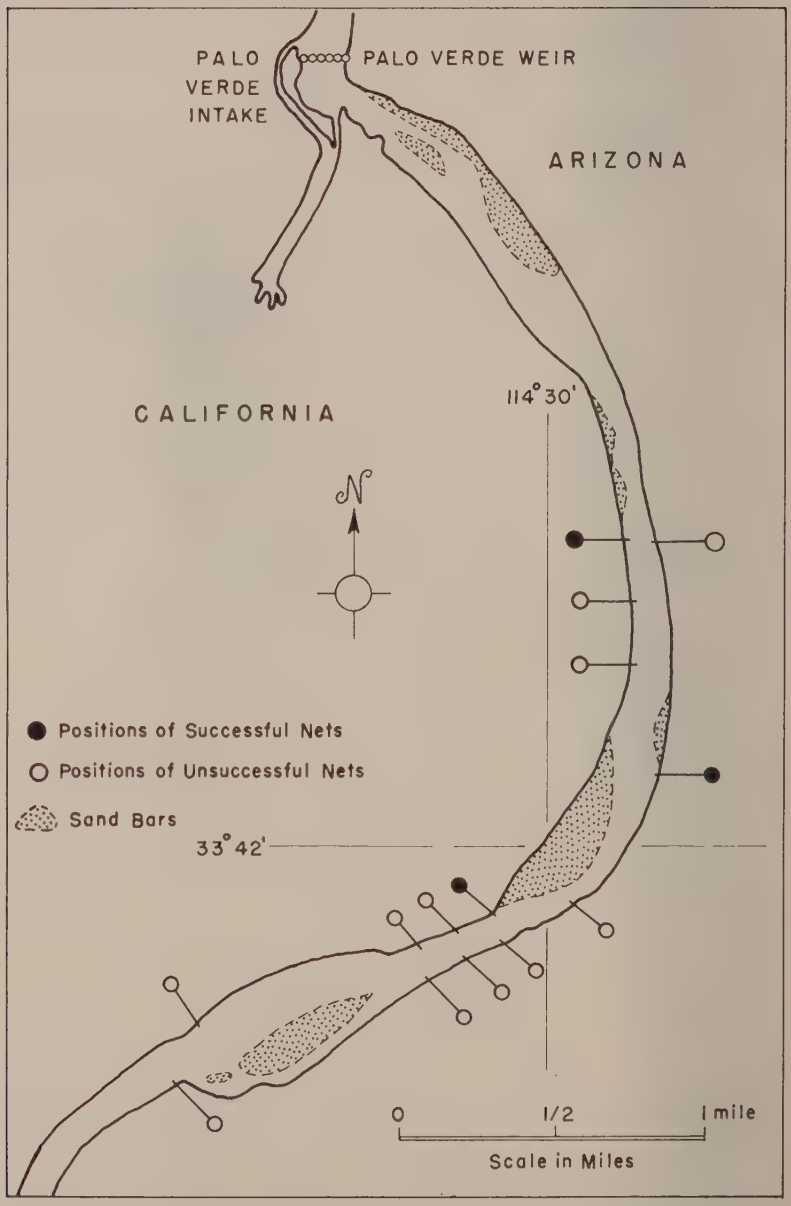

FIGURE 2. Map showing the positions of fyke nets set in April and May, 1954, at Location C.

These results indicate that net location is one of the most important factors in catfish trapping success in the Colorado River. The three productive locations are identified in Figure 2, in anticipation that these, and comparable sets, will be used in any future studies on the Colorado River that involve the trapping of channel catfish.

Tagging of Fish

Two types of tags were used in this study: the disk-dangler tag and the Einar Lea hydrostatic tag.

The disk-dangler tag (Figure 3), a variation of the Atkins tag, is constructed of a cellulose nitrate disk and tantalum wire. It was originally described by Calhoun (1953). Pelgen (1954) and Pelgen and McCammon (1955) used it on white catfish, and it proved to be satisfactory in both field trials and holding experiments. The method used to attach the tags was essentially the same as that described by Pelgen (*op. cit.*).

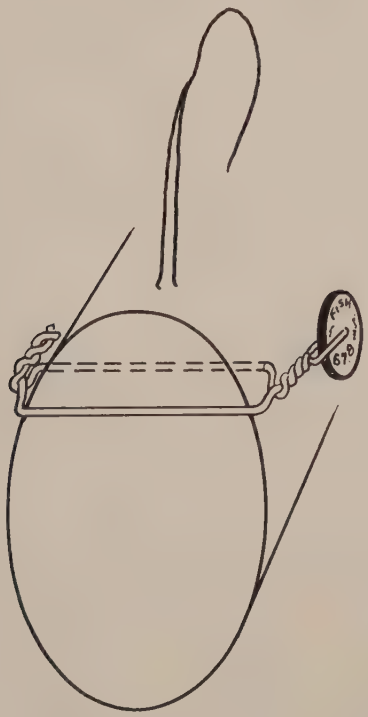

FIGURE 3. The disk-dangler tag shown in place.

The hydrostatic tag was developed by Einar Lea of Norway for use on pelagic marine fishes, such as herring and mackerel. This tag is a water-tight, transparent, plastic tube which contains complete directions for returning the tag printed on a roll of tissue paper. The forward end of the tag is flattened and contains a hole for attaching a wire. The rear end is tapered. A stainless steel bridle is used to attach

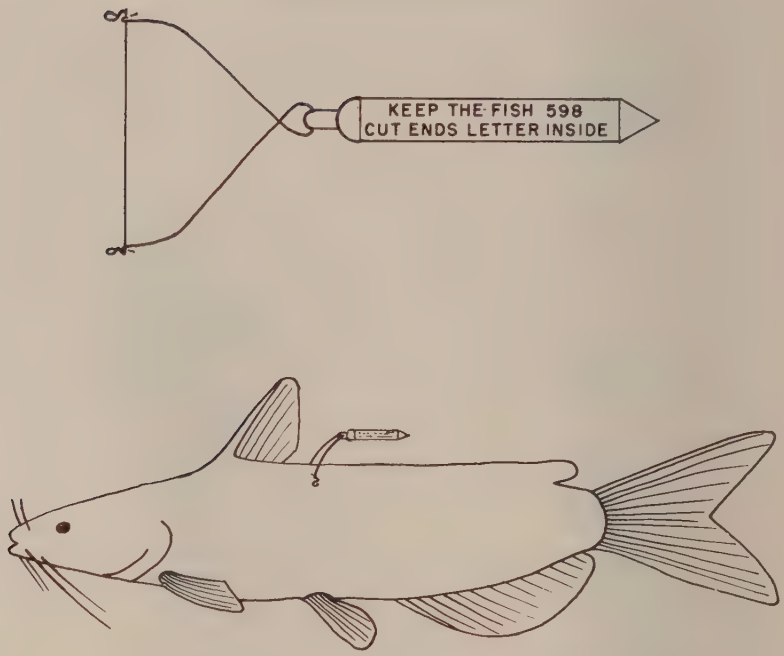

FIGURE 4. *Above:* The hydrostatic tag with wire bridle attached. *Below:* The hydrostatic tag shown in place.

the tag to the fish. The complete tag assembly and point of attachment are illustrated in Figure 4.

The tags are available in several sizes. Those used in this study measured $1\frac{1}{4}$ inches long and nearly $\frac{1}{4}$ inch in diameter. Both ends of the tag are colored bright blue, while the center section is transparent with a yellowish tinge. The contrast in colors attracts immediate attention; however, it has been observed that the colors may be obscured by algae when the tag is exposed to fertile, warm waters.

Hydrostatic tags have two desirable characteristics that are lacking in more conventional tags. First, their specific gravity is almost equal to that of water; thus, in spite of their relatively large size, they do not cause much strain on either the fish or the wire bridle. Second, the instructions offered by the enclosed message are so complete that there should be no confusion or doubt by the fisherman regarding the correct reporting procedure. The message is particularly valuable in tagging studies that rely on voluntary mailed returns from sport fishermen. It is believed that the error resulting from incomplete returns in many such studies can be minimized by the use of such a message.

Although the hydrostatic tag has been successfully used in Europe for several years, its use in the United States has been restricted. Collyer (1954) tested it in an aquarium and a water tunnel and concluded that it would be unsatisfactory for marking yellowtail (*Seriola dorsalis*). He attached tags with both steel wire bridles and nylon, but neither was substantial enough to secure the tags. Pelgen (unpublished

data) tried the hydrostatic tag on white catfish in hatchery ponds. In this experiment, three of 20 tags were lost within one year. Kimsey (1956) used the tag on largemouth bass in an aquarium experiment and found that the steel bridle had a tendency to foul on obstructions, resulting in loss of tags. Additional evidence that the tag is prone to shed was obtained during tagging operations in this study. Four channel catfish that had been tagged with hydrostatic tags were recaptured in the nets within a few days after their release. One of the tags had already been shed and the wire bridles on the remaining three were badly twisted. Several fish tagged with the disk-dangler also were recaptured, with the tags still in excellent condition.

Disk-dangler tags were attached to 164 fish and 100 fish received hydrostatic tags.

Publicity

Since records of tag recoveries were wholly dependent upon voluntary mailed reports from anglers, several methods were used to stimulate interest in the study. Posters, previously described by Pelgen (1954), informing the public of California's catfish tagging program were placed at many points of angler access in the study area. The posters, as well as both types of tag, provided the address to which anglers were to send tag recovery reports. A commendation card bearing a brief history of the tagged fish was sent to each angler who returned a tag, and his name was entered in a prize drawing sponsored by the Foothill Sportsmen's Club of Oakland. This group awarded an annual prize of $100, in addition to many prizes of fishing equipment.

RESULTS

Tag Returns

Since tagging was done during both December, 1953, and April and May, 1954, the returns from each phase were considered separately. Eight returns, amounting to 18.2 percent, were obtained during the first 12 months following the December, 1953, phase. The first year following the second phase yielded 45 returns. This represents a return of 20.4 percent. The total return from both tagging periods was 20.0

TABLE 1

Data on Tags Attached and Tags Returned During First Year

	Tags attached			Tags returned					
				Hydrostatic		Disk-dangler		Total	
	Hydrostatic	Disk-dangler	Total	No.	Percentage of total	No.	Percentage of total	No.	Percentage of total
First phase (December, 1953)	44	None	44	8	18.2		None	8	18.2
Second phase (April-May, 1954)	56	164	220	13	23.2	32	19.5	45	20.4
Totals	100	164	264	21	21.0	32	19.5	53	20.0

percent (53 tags). Table 1 summarizes all data on the number of tags applied and returned during the first year.

The tagged fish ranged from 7.0 to 27.0 inches fork length. Their mean length was 13.4 inches. The mean length of the fish from which tags were returned was 14.3 inches, and the range was 7.6 to 23.0 inches. A statistical test showed that the difference is not significant at the 10 percent level. Thus, tag returns were probably independent of the size of the fish.

The only data on the length of fish at time of recapture was supplied by tag returnees. In some instances, these measurements may have been fairly accurate; nevertheless, it was apparent that many of the lengths given by fishermen were in error. For instance, some of the length data supplied by anglers indicated that the fish had shrunk considerably between time of tagging and time of recapture. Since there was no way to discern the accurate measurements, determination of the growth of tagged fish was not attempted.

Thirty-seven tags were recovered from the 160 fish which were sexed. Of this total, 22 were from females and 15 were from males. It was expected that tags from 21 females and 16 males would be recovered if returns were entirely independent of the sex of fish. Obviously, the difference is not statistically significant. Despite the small size of the sample, the results indicate that there is no difference in the harvestability of the sexes.

Suitability of Tags

As shown in Table 1, 21 (21 percent) of the hydrostatic and 32 (19.5 percent) of the disk-dangler tags were returned during the 12 months following tagging. Statistical procedures showed that the difference is not significant. A deviation, as great or greater, from the number of returns expected theoretically could occur in 75 percent of similar experiments by chance alone.

On the basis of returns alone, it may be concluded that the tags were equally efficient in this experiment. Nevertheless, it is believed that important differences in the tags were not reflected in the rates of return. The proper evaluation and subsequent improvement of both tags are contingent on the recognition of these differences.

Previous holding experiments have demonstrated that the disk-dangler will remain attached to catfish for more than one year, while the hydrostatic tag may become detached. The author estimates that about 15 to 20 percent shedding of hydrostatic tags from catfish might be expected within one year when the tags are attached with steel wire bridles. Loss of hydrostatic tags is attributed primarily to snagging on fallen trees and other obstructions. In the light of this knowledge, it would be reasonable to expect a higher return of disk-danglers than hydrostatic tags. The fact that a greater percentage of hydrostatic tags was returned suggests the operation of some factor or factors that compensated for shedding of those tags.

In the opinion of the writer, the effect of shedding of some hydrostatic tags was offset by more efficient reporting of recoveries of that tag. The enclosed message is believed to have resulted in practically 100 percent reporting of recovered hydrostatic tags. On the other hand, the return of disk-dangler tags is estimated as being only about

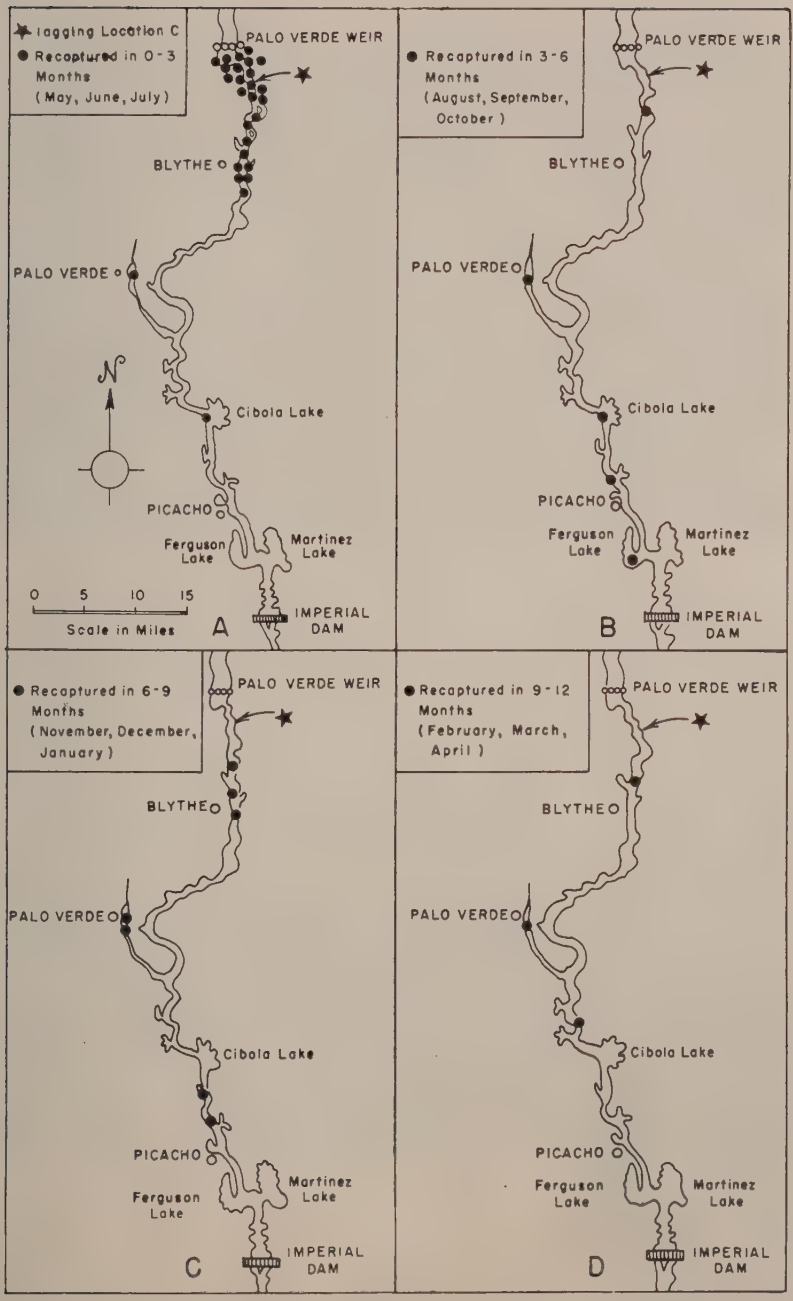

FIGURE 5. Angler recoveries of fish tagged in 1954 at Location C: (a) recaptures during 0-3 months, (b) recaptures during 3-6 months, (c) recaptures during 6-9 months, (d) recaptures during 9-12 months.

85 percent complete. Stroud and Bitzer (1955) obtained data indicating that about 75 percent of recovered strap and cheek tags on warmwater game fishes were reported in Massachusetts when no creel census or reward system was used.

The preceding evidence suggests that the efficiency of hydrostatic tags can be improved effectively by developing a method of attachment that anchors the tags more securely. The effectiveness of the disk-dangler can be enhanced by using every possible means to obtain a complete report of tag recoveries.

Movement of Tagged Fish

Recapture data supplied by anglers who reported tag recoveries provided the opportunity to determine accurately the movements of 50 channel catfish. Eight of these fish were tagged at Locations B and C in December, 1953, and the remaining 42 were tagged at Location C during April and May, 1954.

The fish tagged in 1953 showed practically no movement between time of tagging and recapture, while recovery data from those tagged in 1954 demonstrated that some fish move considerable distances. Individual movements of fish tagged at Location C in 1954, in relation to the interval between time of tagging and recapture, are shown in Figure 5. These movements do not demonstrate a definite pattern of migration. However, it is evident that there was a distinct tendency for fish to move downstream from the Palo Verde Weir area, particularly after the first three months following their release. This downstream movement may be evidence, in part, of a seasonal migration pattern in which fish move upstream during the spring and early summer months and downstream during the fall and winter. It will be necessary to obtain a greater number of tag returns over a longer period of time before any definite conclusions regarding migration can be reached.

The greatest downstream movement was logged for a fish that traveled from the Palo Verde Weir area to Ferguson Lake, a distance of 76 miles, in 180 days. The fastest movement was made by an individual that moved downstream 46 miles in 45 days.

The fact that no fish tagged at Location C were recovered above the Palo Verde Weir (Figures 6 and 7) is strong evidence that this loose rock structure is an efficient barrier to the upstream movement of channel catfish. As illustrated in Figure 5, a number of fish released a few miles downstream were caught at the base of the Weir. Whether these fish were actively attempting upstream migration or were simply attracted to the Weir by the fast current and deep water is a matter of conjecture. Nevertheless, it appears that few, if any, catfish actually move upstream across the barrier.

FIGURE 6. Aerial view of the Palo Verde Weir. *Photograph by California Department of Fish and Game.*

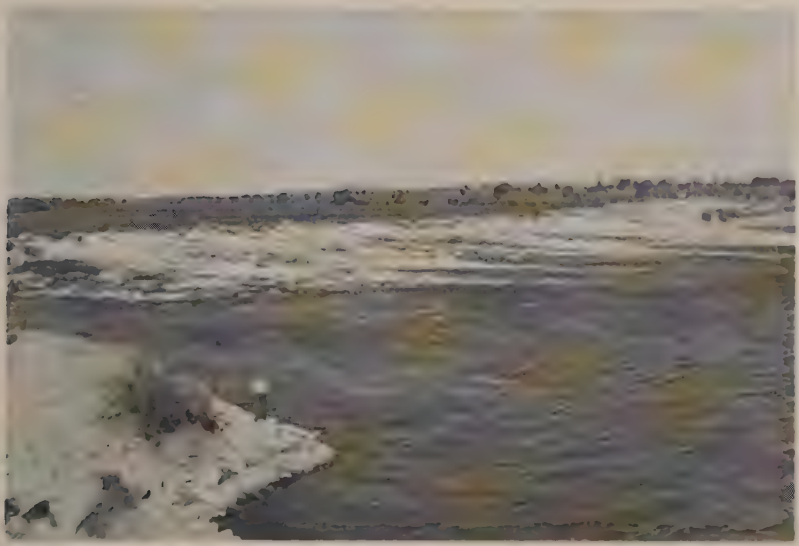

FIGURE 7. The Palo Verde Weir. Shore anglers usually fish in the eddies shown at the left of the photograph. Boat anglers fish the edge of the white water along the face of the weir. *Photograph by the author.*

Harvest

As stated previously, one of the objectives of this experiment was to obtain a tentative estimate of the percentage of the Colorado River channel catfish population that is harvested each year by anglers. Since the study was preliminary in nature, it was realized that such an estimate would be of doubtful value in regulating the fishery, except as an indication of the general level of exploitation. It will be necessary to tag a much larger number of fish in more sections of the river before a valid estimate of the annual rate of harvest can be obtained from tag returns.

Despite the relatively small number of fish used in the study, the return of 20 percent of the tags during the first year indicates that the present rate of harvest is not excessive.

ACKNOWLEDGMENTS

The author is indebted to California Department of Fish and Game co-workers Leonard Fisk, J. B. Kimsey, and Vincent Catania for invaluable assistance in trapping and tagging the fish. A special note of gratitude is due Vincent Catania, who also constructed the fyke nets used in trapping operations. Fellow employees David E. Pelgen and R. D. Beland provided many helpful suggestions regarding the general planning of the study. The cooperation of the Foothill Sportsmen's Club of Oakland is gratefully acknowledged. Mr. Ed Busalak, of that group, shouldered most of the responsibility for promoting and organizing the prize drawings.

SUMMARY

The sport fishery for channel catfish in the lower Colorado River is a resource that is vitally important to California's anglers. However, information necessary to manage the fishery is lacking. In 1953, an exploratory tagging study was begun to provide preliminary data on trapping and tagging techniques, annual rate of harvest, and migrations of channel catfish.

The fish were trapped and tagged between Parker and Imperial dams. Trapping during the winter months yielded very few fish, while spring trapping was fairly productive when fyke nets were fished immediately below sand bars.

A total of 264 channel catfish was tagged, 164 with disk-dangler tags and 100 with hydrostatic tags. Anglers reported recovery of 53 tags (20 percent) during the first 12 months.

Twenty-one percent of the hydrostatic tags and 19.5 percent of the disk-dangler tags were returned. The difference is not statistically significant; however, it is believed that the nearly equal rates of return failed to reflect certain fundamental differences in the effectiveness of the tags. Shedding of hydrostatic tags was probably offset by more complete reports of recoveries of that tag than of disk-danglers. The return of disk-dangler tags was estimated to be only 85 percent complete.

Statistical procedures demonstrated that tag returns were apparently independent of both the size and sex of the fish.

Data on the movement of tagged fish indicated a definite tendency for channel catfish to move downstream from the Palo Verde Weir during the fall months. This movement may be partial evidence of a regular, seasonal migration. The Palo Verde Weir is, apparently, an efficient barrier to the upstream movement of channel catfish.

The return of 20 percent of the tags in the first year indicates that the fishery is not overexploited; however, a larger number of fish will have to be tagged before accurate information on both the annual rate of harvest and migration can be obtained.

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LARGEMOUTH BASS TAGGING[1]

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It became apparent in the early phases of the California warmwater fisheries investigations that a good tag for largemouth bass, *Micropterus salmoides*, was needed. Long-range mortality and rate of harvest data were not forthcoming from information obtained by conventional tagging methods. One reason for this was the rapid shedding of tags.

This report summarizes the results thus far obtained from a study of different types of tags in the field and in the aquarium. They are not entirely conclusive and the study is a continuing one. Enough information has been obtained, however, to make a discussion of results profitable at this time.

Acknowledgment is due Dr. Earl S. Herald, who made an 800-gallon observation tank (Figure 1) available at Steinhart Aquarium, San Francisco, for a year and a half. Almo Cordone, Ed V. Dwyer, Leonard O. Fisk, and R. R. Bell all assisted in either tagging, recording, or making observations.

FIGURE 1. Tagged largemouth bass in display tank at Steinhart Aquarium.

[1] Submitted for publication May, 1956. A portion of this work was performed as part of Dingell-Johnson Project California F-13-R, "Black Bass Tagging", supported by Federal Aid to Fish Restoration funds.

TYPES OF TAGS USED

Strap Tag

This type of tag is most commonly used on warmwater fishes and many of the classic use studies were carried out with strap tags. In the present study No. 1 monel strap tags, 2 mm. wide and 8.5 mm. long, were used. They are usually applied by special crushing pliers and when closed have an oblong opening 2.5 mm. by 6.3 mm. However, by squeezing they can be forced into a more or less circular form with an opening approximately 5 mm. in diameter.

Tagging in the Field

At Clear Lake, Lake County, both forms were used. They were placed on the lower jaw halfway between the epiphysis and the angle of the mouth (Figure 2, A). The fish ranged from 6.5 to 9.0 inches in fork length. Of a total of 108 tags attached, three, or 2.8 percent, were returned by anglers. The longest, confirmed elapsed time between tagging and return was 41 days.

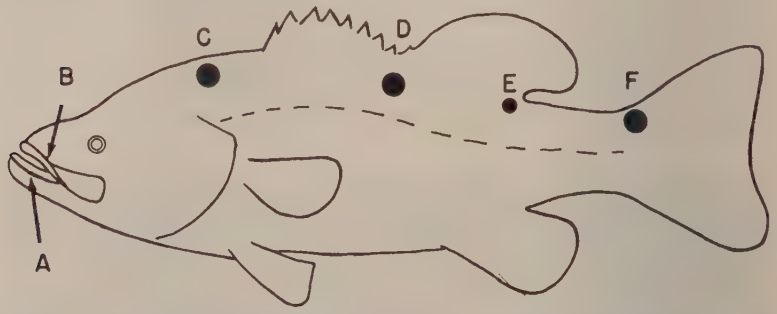

FIGURE 2. Location of experimental tags. A and B, flat and rounded strap tags; B, round jaw tag; C, Petersen disk; D, Petersen disk, disk-dangler, and plastic "spaghetti"; E, Einar Lea hydrostatic; F, Petersen disk.

Not enough returns were received to show a significant difference between rounded and unrounded tags. The use of strap tags was discontinued at Clear Lake after the 48th day of tagging. At that time every net-recaptured fish had a large, raw tag sore and was in obvious distress because of it.

Aquarium Experiment

Because of the popularity of this tag, further tests were carried out in an 800-gallon observation tank at Steinhart Aquarium. Sixteen fish from 7.25 to 8.0 inches in fork length were tagged on August 4, 1953. Five had conventionally flattened jaw tags attached in the same place as the Clear Lake tags, five had similarly attached rounded tags, and six had rounded tags attached around the point where the maxillary and the premaxillary overlap (Figure 2, B). Two weeks after tagging all tags had caused serious sores, although none had been shed. No change was noted at the end of six weeks. On December 1, 1953, four lower jaw and two upper jaw tags had been shed, leaving badly split jaws.

By July 7, 1954, when the experiment was terminated, only two tags remained. These were both lower jaw, rounded tags.

The 14 fish that shed their tags experienced a mean percentage increase in length of 28 percent during the period of the test, while the two fish retaining their tags showed only 6 percent increase. One of these two tags was still in place on July 25, 1955. In the nearly two years it had been tagged this bass had gained 17 percent in fork length over its size at tagging. This is about one-third the increase that could be expected. Therefore, it appears that jaw tags are retained best when growth is slow.

Hatchery Experiment

Round jaw tags similar to bird bands were applied to the upper jaw on August 10, 1954. These tags were of monel metal 3.5 mm. wide and 8 mm. in diameter. They encircled the point where the premaxillary and maxillary overlap (Figure 2, B). Fifty tags were attached and 20 of these were shed within 30 days. The fish were kept in a dirt-bottom hatchery pond with a moderate amount of aquatic plant growth. The remaining tags had begun to wear an irritated notch in the lower jaw. This tag appeared to inconvenience feeding less than any other of the jaw tags. Some interference with the oral valves was observed. The tagged fish ranged from 6.2 to 9.0 inches in fork length. The shedding was caused by the constant rubbing of the tag on the bottom or sides of the pond. The place from which the tag was shed healed rapidly and in most instances no serious deformity resulted.

Evaluation

In fast-growing, active fish such as yearling largemouth bass, jaw tags should not be relied upon to give dependable data. In order to allow for growth, the size of tags placed on yearling bass must be so large that the tags interfere seriously with feeding and swimming. If the tags are initially of a size proportionate to the size of the fish, growth soon forces them out.

The use of this tag on larger bass, whose growth rate has decelerated enough to cause a corresponding lesser rate of tag loss, may produce one-season angling mortality data but does not yield the more extensive natural mortality information.

P. A. Douglas (unpublished data) reported that at San Vicente Reservoir, San Diego County, California, a six-month tag return of 52.9 percent for jaw tags placed on 70 introduced bass with a mean weight of 2.6 pounds and a mean fork length of 15.5 inches was obtained. Fifty percent were returned in four months, with an additional 2.9 percent received the sixth month and, although fishing continued, none after that time. He obtained a tag return from the same water of 51.7 percent in three months from another introduced group of 149 bass with a mean weight of 1.1 pounds and an estimated mean fork length of 12.5 inches. An additional 6 percent were recovered in the next eight months.

Chance (1955) reported resident largemouth bass jaw tag returns of 41.6 percent and 41.2 percent from two Tennessee Valley reservoirs. The tag returns were 95 and 94 percent complete during the first year. The size of the fish tagged was not reported.

Manges (1950) reported an over-all jaw tag return of 18.4 percent for largemouth bass in Norris Reservoir, Tennessee. This was the combined result of four separate tagging studies, in which known second season recaptures of this species totaled one. The size of the tagged fish was not reported.

Dequine and Hall (1950) had an average jaw tag return of 22.9 percent from largemouth bass in six lakes in Florida. This was 92.4 percent complete within 30 weeks of their release. Three returns were reported after one year. The size of the tagged fish was not reported.

The nonreturn of tags after the first year in these studies is the result of either shedding or high natural or tagging mortality. In the light of the aquarium and hatchery observations, it appears shedding is the more likely cause.

Whether or not jaw tags have an influence on the rate at which the tagged fish are harvested is not known. The rate may be accelerated over that for untagged fish, due to irritation and interference with normal feeding. An unfamiliar and unpleasant jaw tag may well make the usual prey at least temporarily unavailable. The quiescent bottom baits or the hampered live minnow baits may be more attractive. Also, plugs and artificial lures may be more readily taken during this period, because of their method of presentation by the angler. The initial high tag returns may substantiate this viewpoint.

PETERSEN DISK TAG

This type of tag consists of two cellulose nitrate buttons one-half inch in diameter and 0.045 inch thick at each end of a soft tantalum wire 0.020 inch in diameter passing through the fish. The buttons are prevented from sliding off by a simple twist knot at each end of the wire.

Aquarium Experiment

This tag was tried in three positions. One was on the back, about half way between the occiput and the anterior insertion of the dorsal fin (Figure 2, C). Another was on the back, between the spinous and soft dorsal fins (Figure 2, D). The wire at each of these positions passed through the fish slightly above the midway point between the lateral line and the midline of the back. The third position was on the caudal peduncle (Figure 2, F), in the equivalent position described by Calhoun (1953) for striped bass, *Roccus saxatilis*.

Figure 3 shows the growth in width plotted against the growth in fork length at these three positions. It is rather apparent that the rate of growth at the two dorsal locations is such that the slack will soon be taken up and the tags will be forced upwards and eventually out. This occurred in the aquarium experiments begun July 7, 1954.

The soft tantalum wire was, in two instances, actually untied by the pressure of growth. Of the 12 tags placed in these areas (6 at each location), all were well on their way to being forced out at the end of seven months.

The 10 tags placed on the caudal peduncle had the wire passing through the hypural plate. The 4 tags retained at the end of 7 months were, in each instance, gradually forcing their way backward and

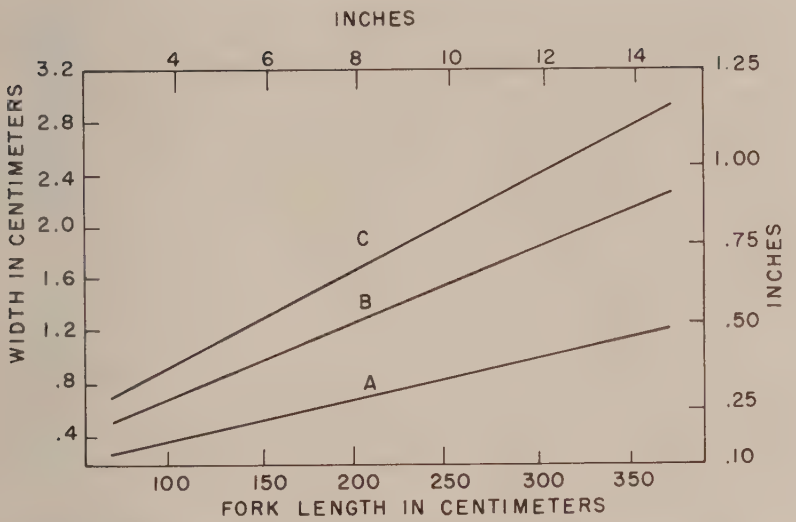

FIGURE 3. Regression lines of fork length and width for three tagging points on largemouth bass. Line A is for the caudal peduncle (Figure 2, F). Line B is for the position on the back between the spinous and soft dorsals (Figure 2, D). Line C is for the position on the back midway between the occiput and the anterior insertion of the spinous dorsal (Figure 2, C).

upward. Six had been completely shed. Even though the growth rate at this point is least, the bone structure is not heavy enough to prevent the wire from sawing its way out.

Evaluation

Petersen disk tags do not allow for growth. Tags placed loose enough to allow for growth move enough to cause bad sores.

Red, white, and yellow tags were used. Unlike tagged rainbow trout confined in a small area (German and LaFaunce, 1955), the bass did not attack any one color more than another. There was no evidence of damage to the fish by other fish biting at tags.

The resistance and subsequent pulling out of the tags on the caudal peduncle may be reduced by using a tag of smaller size. In this instance a Petersen disk tag may be useful.

STAPLE TAG

The staple tag (Figure 4, A, B), as described by Calhoun (1953) and used by Pelgen and McCammon (1955) on white catfish, *Ictalurus catus*, was placed on 240 largemouth bass in Clear Lake, Lake County, in the summer of 1953. These fish varied from 8.5 to 19.0 inches fork length, with a mean of 10.1 inches.

This tag consisted of two soft tantalum wires with a disk on one side secured by a simple twist knot on the other side. The wires passed though the fish between the spinous and soft dorsal fins (Figure 2, D) about half way between the mid-dorsal line and the lateral line. The wire and disks were of the same specifications as those used in the Petersen tag observations.

It soon became apparent that this tag was unsatisfactory. A large sore formed rapidly and the tag was forced back by rubbing, so that it turned completely over (Figure 4, C). Its ultimate position made it, in effect, a disk-dangler tag. The severe sore caused the early abandonment of this tag.

Despite this, a two-year return of 66 tags (22.2 percent) was obtained, of which 39 (59.1 percent of the total return) were received the first year and 25 (37.9 percent of the total return) the second year. In the first half of the third year two tags have been returned.

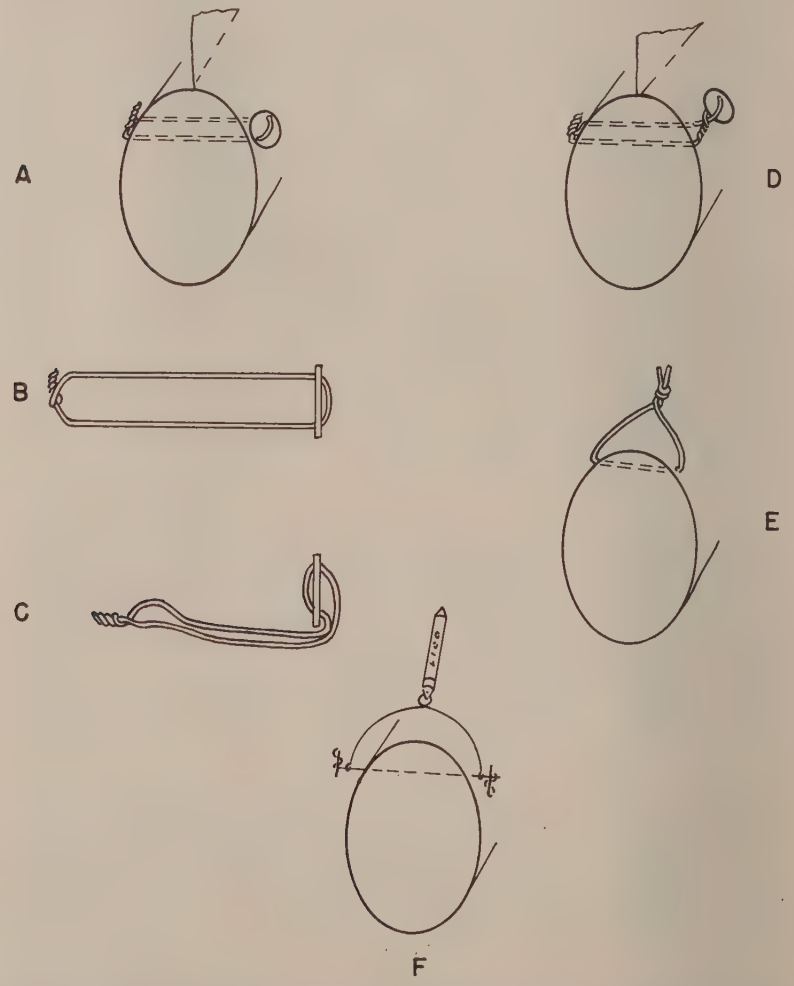

FIGURE 4. Diagrams of tags used: A, staple tag in place on fish; B, normal form; C, in the turned over position at which time it acts as a disk-dangler tag; D, disk-dangler; E, plastic "spaghetti"; F, Einar Lea hydrostatic.

DISK-DANGLER (ATKINS) TAG

This is a modification of the Atkins tag described by Calhoun (1953) and used by Pelgen (1954) and Pelgen and McCammon (1955) on white catfish. It consists of two wires passing through the fish, knotted on one side with a pendant, although rigidly-fixed, disk tag on the other side (Figure 4, D).

Field Experiment

At Clear Lake, Lake County, 82 of these tags were placed on bass from 9.0 to 20.25 inches in fork length. A total of 26 (31.7 percent) was returned in two years, of which 14 (56 percent of the total return) were received the first year and 11 (44 percent of the total return) the second year.

Aquarium Experiment

Ten of these tags were placed dorsally between the spinous and soft dorsal fins (Figure 2, D) on yearling bass in Steinhart Aquarium during July, 1954. When the experiment was terminated in February, 1955, all tags were still in place. Except for one swelling, all fish were in excellent condition externally. No sores were in evidence, other than a few red areas under tags. In most instances the knot was completely covered by skin and scales. The knot could be drawn into the flesh as far as the point where the proximal pterygiophores and the neural spines interlock.

For every two-inch increase in fork length the largemouth bass in California on the average gains a corresponding 0.1 inch in width at this point (Figure 3). In Clear Lake, according to data from Murphy (1951), bass gain in fork length at an average rate of about 3 inches per year after the first year. A 9.0-inch fish is about 0.6 inch wide where the two-wire tag is attached. If growth is normal, this allows about 0.3 inches of growth in width or about two years before the wire has migrated inward far enough to press on the neural spines and proximal pterygiophores. The length of time the tag remains effective is also dependent upon whether or not the tag is immobolized, a condition readily obtained with tantalum wire. Flesh actually appears to become attached to it.

Many factors affect the time these tags can be expected to remain on the fish. Slower growth, dimpling, looseness of tagging, and the pulling in of the disk stalk all affect the time a tag will be effective.

Two disk-dangler tagged fish died en route from the aquarium to the hatchery holding pond. These, together with another later casualty, were dissected to determine the effect of the tag on the muscle and bone structure of the fish. One of the dead fish was the individual in which the swelling had been noted. No other irritation was evident until the skin was removed, when a discolored area about 1 inch long and $\frac{1}{2}$ inch wide was revealed. The knotted wire had moved into the flesh about $\frac{1}{4}$ inch. A pocket of necrotic tissue had formed at the point where the forward wire passed though the proximal pterygiophores and the neural spines. A similar condition was found in the two remaining fish. In each instance, however, the hind wire, even though pressing against bone, had not formed any such pocket.

The wire frame when initially applied has a rectangular shape. In the above tags the wires had been distorted into a rough right triangle with the hypotenuse (the fore wire) coming diagonally through the fish and the base (the hind wire) still in place. Later examination of other fish showed that when this condition had existed for a longer period of time the necrotic pocket had virtually disappeared. Stabilization appeared to be taking place.

Force diagrams showed that when a rectangular wire tag had the stalked disk pushed through an arc of 10 degrees with the fulcrum (neural spine) in the center of the rear wire, the center of the forward wire moved about three times as far as it did when similar movement of the stalked disk occurred in a triangular wire tag.

It would then appear that if the wires were applied in a triangular shape initially, the internal irritation would be reduced. The elimination of the long stalk on the disk would also tend to limit movement.

PLASTIC "SPAGHETTI" TAG

Wilson (1953) and Collyer (1954) have described this tag in their tagging studies on tuna and yellowtail. The tags of this type (Figure 4, E) used on largemouth bass were made of white No. 20 vinylite tubing. No jacket or core was used. They were secured with a simple figure-eight knot.

In the aquarium observations, 10 of these tags were placed dorsally between the spinous and soft dorsal fins (Figure 2, D). None of these tags was shed. Although some initial swelling and redness occurred, no external sores were noted.

Dissection of three individuals at the end of seven months showed no irritation. The hole through which the tag passed appeared to be lined with strong membrane-like scar tissue. In one instance the edge of the soft dorsal was worn by rubbing of the tag.

The possibility that the tag would catch on submerged brush was not adequately tested. These tags placed on brown bullheads held in an aquarium full of brush did catch. In one instance a tag was torn out.

No knots came untied, although this is a definite possibility that has been demonstrated (personal communication) in rapid-swimming marine fish. This might be circumvented by using small metal clips instead of a knot. A few "spaghetti" tags secured with No. 1 strap tags are now being tested.

EINAR LEA HYDROSTATIC TAG

This tag (Figure 4, F) consists of a message sealed in a tubular plastic hydrostatic tag and secured to the fish with a stainless steel bridle. Einar Lea developed the tag and has used it successfully in Norway to tag ocean fishes.

Four of these tags were used in an aquarium experiment lasting 11 months. Two were placed between the spinous and soft dorsal fins, with the bridle passing through the interlocking proximal pterygiophores and neural spines (Figure 2, D). Two others were placed just behind the soft dorsal, at the fore part of the caudal peduncle (Figure 2, E).

The two dorsal tags were retained for the duration of the experiment. The wounds never healed and, although not large, allowed considerable movement of the bridle. The fish were moved at the end of the aquarium experiment to hatchery ponds with moderate weed growth. One month after this, when they were seined for examination, both bridles had shifted so that the tag was riding on the side of the fish with the bridle knot on one end inside the fish and the other knot protruding at an angle from the side of the fish. The bridles became easily fouled in the net. The thin stainless steel wire was cutting upwards rapidly and would have been shed in a short time.

The other two tags, placed at the fore end of the caudal peduncle, were shed after six months in the aquarium. The resultant scars indicated that this was caused by the slight but persistent backward pull of the hydrostatic cartridge during the somewhat limited swimming in the 800-gallon aquarium.

When fouling on debris or weeds occurs, the Einar Lea tag with its present stainless steel bridle can easily saw its way out. The principle of the sealed message is good and consideration is being given to developing a more suitable bridle arrangement.

SUMMARY

The performance of six different kinds of tags attached to largemouth bass was observed in the aquarium and in the field. Although limited in some instances, these observations support the following conclusions.

Strap tags used on various parts of the mouth do not yield adequate mortality data because of their rapid shedding, apparently caused by rapid growth. In yearling fish, a tag large enough to allow for growth is too cumbersome and a smaller tag is shed too rapidly.

Twenty of 50 round jaw tags fastened over the premaxillary and maxillary bones were shed in 30 days.

Petersen disk tags are shed too quickly, if growth is normal.

Two-wire staple tags become stable only after the disk turns over, in which instance they in effect become disk-dangler tags. The wires are exposed to excessive abrasion when this occurs.

Two-wire disk-dangler tags are long lasting and none has been shed. A change in the shape of the wire frame from rectangular to triangular is indicated.

Plastic "spaghetti" tags were not shed in the aquarium, nor have they caused sores. The possibility of their hanging up on brush has not been tested adequately and an improvement in fastening may be needed.

Einar Lea hydrostatic tags have a hard, small-diameter, stainless steel wire that has a tendency to cut out or change position and hang up on nets and vegetation. Unless this bridle arrangement is improved, they are not satisfactory for largemouth bass tagging.

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A SIMPLE OPTIC BENCH FOR SCALE PHOTOMICROGRAPHY[1]

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During the course of an age and growth study on the barred perch, *Amphistichus argenteus*, and the yellowtail, *Seriola dorsalis*, a need arose for some means of taking suitable photographs of fish scales.

The available equipment for scale photography at the California State Fisheries Laboratory was found inadequate and difficult to use. The authors believed that modifications to the equipment available at the laboratory could provide an optic bench which would be compact for storage, easily portable, simple, and efficient in photomicrography. With this in mind the optic bench (Figure 1) was constructed.

Materials Used

1. Kine Exakta camera without the lens.
2. Bausch and Lomb triple-purpose microprojector.
3. Bausch and Lomb No. 31-33-77 microscopic illuminator; aspheric focusing condenser; ribbon filament bulb and a three-intensity transformer.
4. Two pieces heavy-gage sheet metal, 25 inches x 3 inches.
5. One piece plywood, 40 inches x $7\frac{1}{4}$ inches x 1 inch.
6. Microscope objective lenses:
   16-mm. objective
   32-mm. objective (Micro Tessar)
   48-mm. objective

CONSTRUCTION AND USE OF BENCH

Each piece of three-inch wide heavy sheet metal was bent at right angles to form a "⌊" shaped channel 6 inches x 12 inches x 6 inches, and the ends of this channel were then bent outward at right angles to form a $\frac{1}{2}$-inch flange. These flanges were drilled for attachment to the plywood baseboard. The two formed pieces of sheet metal were then inverted and mounted parallel to one another, on one end of the baseboard, with a 3/16-inch separation between them. This separation allows for mounting the camera by a knurled screw and for the transport of the camera along the 12-inch track, thus providing ease in moving and maintaining optical alignment of the camera.

The microprojector, stripped of its light and condensing system, was mounted on the plywood baseboard, leaving a two-inch distance between its fully extended focusing mount and the proximal end of the camera track.

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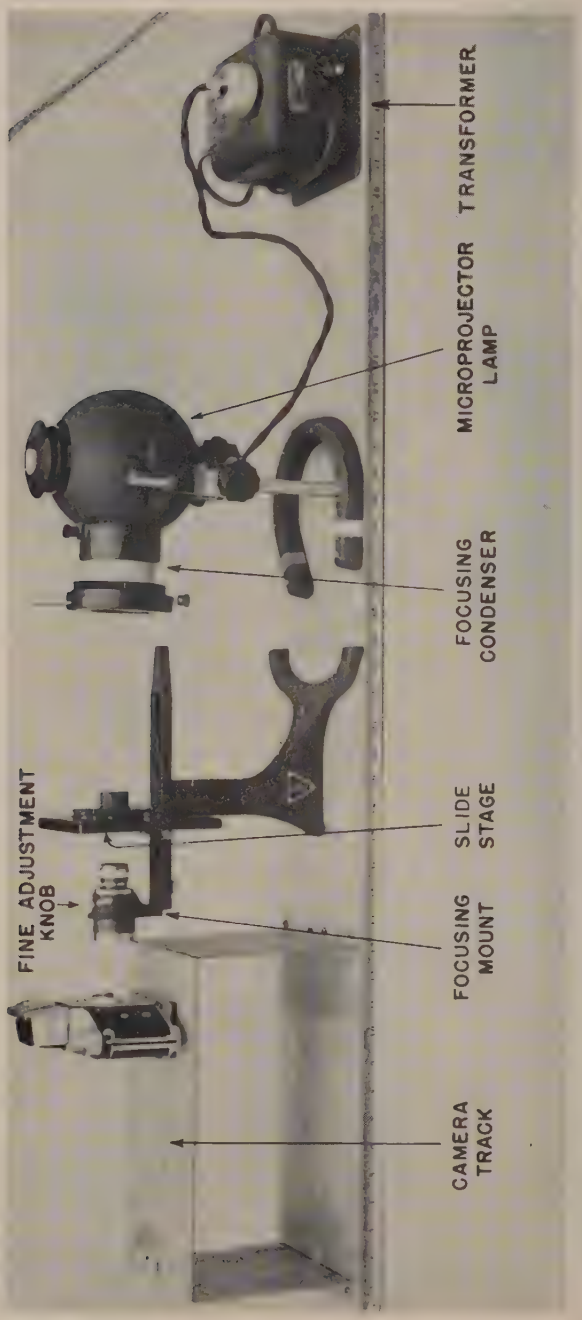

FIGURE 1. Optic bench with all the components mounted on the baseboard. Ruler is included only to indicate size. *Photograph by Jack W. Schott.*

The microscope illuminator with its condenser lens in retracted position was mounted 13½ inches from the proximal end of the camera track. For large fish scales it may be desirable to position the illuminator at a somewhat greater distance from the end of the camera track. The microscope illuminator must be far enough from the fish scale so that the projected illuminated ribbon filament will give evenly distributed light throughout the scale field. To obtain even illumination and to reduce light refraction the illuminator condenser was adjusted so that the edge of the illuminated ribbon filament was focused sharply upon the camera's ground glass. Extraneous light, admitted from the space between the camera and the focusing mount, can be eliminated from striking the film by use of adapter rings, cylindrical tubes, or by subduing room light.

When taking photographs of various sized scales, the camera should be moved forward or backward until the scale image fills the field of the camera's viewing glass. With this accomplished, the fine adjustment of the focusing mount should be used to give a clear, sharp image for each photograph.

Of the three objectives, the 32-mm. Micro Tessar was the most versatile for photographing different sized scales. The other objectives were restricted to smaller or larger scales.

The transformer intensity, when using the 32-mm. Micro Tessar, is dependent on the scale size. With smaller scales the camera is positioned at a greater distance from the microprojector and consequently it is necessary to use the high transformer intensity. With larger scales the converse is true and the low or medium intensity is used.

Using Plus-X film, a 32-mm. objective, and a shutter speed of 1/250 of a second, suitable film exposures were obtained of a seven-millimeter scale at low or medium transformer intensity and of a one-millimeter scale at high transformer intensity.

NOTE

CONDITIONED SPACE RESPONSE IN AN AQUARIUM TANK BY THE CALIFORNIA YELLOWTAIL, *SERIOLA DORSALIS*

In September, 1953, Steinhart Aquarium received 11 California yellowtail from the California Department of Fish and Game research vessel N. B. Scofield. These were placed in a 1,400-gallon tank with a surface area of 79 x 93 inches and a depth of 44 inches.

Despite the fact that this is one of the few species of large, fast-swimming fishes that do well in a small tank, it was believed they needed a greater volume of water. Accordingly, a wall between two tanks was removed to provide a rectangular 2,746-gallon tank. Thus, on September 1, 1955, after two years in the original small tank, the yellowtail were transferred to the new tank of almost twice the previous capacity (Figure 1). It should be noted that the old tank was immediately adjacent to the new tank, so that both old and new had the same orientation.

FIGURE 1. Visitors watching the yellowtail in the left half of their 2,746-gallon tank. The bat rays are in the right side of the yellowtail tank. *Photograph by Moss Photography, November 10, 1955.*

Surprisingly, the yellowtail made no use of the additional swimming space but remained almost constantly in the left or east section of the tank. This condition continued for three weeks, by which time one fish would occasionally swim into the unused portion of the tank. On rare occasions it would be followed by the other 10 fish in schooling formation. This strange condition continued for two months with little change. In the third and fourth months the yellowtail gradually accepted the additional space and eventually used the whole tank about one-half of the time. In the fifth and sixth months there was little indication of their earlier preference for the left side of the tank. However, the strange enigma of why the left or east rather than the right or west side of the tank should have originally been selected remains unanswered.—*Earl S. Herald, Steinhart Aquarium, California Academy of Sciences, San Francisco 18, California, May, 1956.*

REVIEWS

The Spirit of the Wild

By William J. Long; Doubleday and Company, Inc., Garden City, N. Y., 1956; 256 p., illus. $4.

Dr. Long is familiar to many through his series of nature articles which appeared in *Sports Afield* and *Sports Illustrated*. These concerned some of the common game and fur-bearing mammals and are reproduced in this book.

Although Dr. Long published his last book in 1923, he kept observing nature and writing about it until his death in 1948. This volume is the first in a proposed series of three nature books compiled from his unpublished material. The second book will be about birds and the third about fish.

The contents are divided into two parts. The first deals with the individual animals and the second their general behavior.

From the Grand Canyon in Arizona to the forests of New Brunswick, Dr. Long discovered, tracked, and observed a great variety of animal life over a long span of years. He was primarily interested in the mannerisms and characteristics of wild animals and, in particular, those features or oddities which bestow to each animal the mark of an individual. These he portrays in delightful fashion through vivid, living descriptions and captivating style.

Especially good are the descriptions of beaver courage on page 145, and a porcupine "throwing" its quills on pages 100 and 101. The chapter on jack-light witchery is outstanding in the artistry of the descriptions, while the chapter on the question of animal reason is memorable for its summary and analysis of the classic literature on reason versus instinct. On this subject the author concludes,

> "More than this, instinct is not the animal, and reason is not the man. With man's reason are his will and emotions—love, fear, courage, generosity—none of these separate and distinct entities, but all combined together to make the man. With the animal's instinct are other things that we must consider—something that looks like will, and emotions of love, fear, courage, and self-denial, which are undeniably like those in our own hearts, however much they differ in degree. Since we share so much in common of the physical and emotional life, it is hardly more than to be expected that the animal himself, apart from his instinct, should share something of our rational faculties."

There are two features of this book which detract from its over-all excellent quality. The occasional slaps at professors and biologists may have been warranted but seem incongruous for a man of Dr. Long's stature.

A serious drawback to the book, in the reviewer's mind, is the author's views on predators, which are more akin to the hunter than the naturalist. For example, on page 80 he says, "Up to this time I had no thought of stalking lions afoot: now the remembrance of that bleeding doe brought with it an impulse to still-hunt her terrible enemy." On page 220 he again refers to the mountain lion, "Whatever sympathy one might otherwise have felt for the big cat had vanished at sight of his claw marks gashing the side of a doe, * * *" The great horned owl is called a savage bird and the Cooper's hawk is scorned as a tireless freebooter and the worst of the game-bird killers.

Such terminology is reminiscent of movies starring Howard Hill, the noted archer, which drone with such adjectives as savage, treacherous, vicious, dangerous, etc. This is sad; an old sadness which today's public is not buying.

Those familiar with the works of Sigurd Olson and the late Aldo Leopold and many other famous naturalists who love all wild things and understand and appreciate their place in nature will be dismayed and perplexed by this facet of Dr. Long's thinking, particularly in view of his seemingly firm grasp of animal behavior. —*Almo J. Cordone, California Department of Fish and Game.*

Resources and the American Dream

By Samuel D. Ordway, Jr.; The Ronald Press Company, New York, 1953; vii + 55 p., 5 figs. $2.

Our conservationists seem to be divided into two groups, the optimists and the pessimists. The first group thinks that every day in every way we are getting better and better, that our inventiveness will overcome all obstacles, and that our natural resources will meet all demands of our increasing population indefinitely. The pessimists, on the other hand, think that we are on the way to becoming a nation of "have-nots", that our demands on our national resources are threatening the American standard of living, and that our resources are going the way of the buffalo and the passenger pigeon.

Mr. Ordway recognizes both of these viewpoints; a review of the facts leads him to conclude that a certain necessary reduction in our way of living is coming. He is not enthusiastic about the prediction of "steaks made from sawdust, cookies from kelp, or vitamins from algae in the sea". He asks and answers two questions: (1) "How valid are the optimistic claims of scientists on the one hand and the predictions of prophets of doom on the other?" (2) "What are the limits, if any, to economic and industrial growth?"

In this small book Mr. Ordway has accumulated an abundance of stubborn facts and charts to support his conclusion that we are using up our capital land, minerals, and wood at an alarming rate. "Since 1945 our food production has increased 50 percent less than our population." The expansion of industry is eating up our productive farm land, while at the same time through misuse much of our acreage is becoming unproductive. In the light of our soil bank plan and our accumulating surpluses we may laugh this off, but before doing so we had better weigh carefully the evidence put before us by the author. His charts are not to be contradicted.

For those who care to philosophize about our present outlook, the chapter on "The Good Life" is refreshing.

This is a stimulating little book, clearly written, and provides an excellent introduction to the whole problem of conservation.—*Willis A. Evans, California Department of Fish and Game.*

Fishing With Natural Insects

By Alvah Peterson; The Spahr & Glenn Company, Columbus, 1956; x + 176 p., 63 figs. $6.

The subtitle, "A Handbook of Insects for Bait Use", is far more descriptive than the title. Mr. Peterson, an entomologist, does not discuss the techniques of fishing with insects. He explains the techniques of capturing, preserving, and rearing insects that are large enough to impale on a hook.

The text adequately describes insects and their larvae, selected from 13 orders. Life history, distribution, and physical details are given for each order, family, and genus mentioned. The information is presented in clear, simple form that permits quick reference and pleasant reading. One of the most appealing aspects of the book is the manner in which some of the insects and their habits are described. The author discusses the crickets, for instance, as though they were close friends.

Amateur naturalists and anglers alike will enjoy the continuous thread of information on the capture and rearing of insects. How many of us have placed our bait in a jar or can and found it dead within a few hours?

A chapter on the location and food of common fishes is rather vague with respect to distribution and tends toward the bizarre regarding foods.

The illustrations range from fair to excellent. Many of the photographs have been retouched for clarity, while others are almost perfect in detail. I especially liked the photographs of oil paintings by W. C. Costello.

Although the price is high, there is a great deal of factual and interesting information in this little book. —*Richard Haley, California Department of Fish and Game.*

Forest and Range Policy

By Samuel Trask Dana; McGraw-Hill Book Company, New York, 1956; xii + 455 p. $6.50.

The complete title is "Forest and Range Policy, Its Development in the United States." This is the twenty-fourth work in the American Forestry Series of textbooks, which dominates the forestry text field.

The first inception of forest regulations in colonial times marks the starting point of the chronology. As times changed, policies changed. The object of the book is to present "some knowledge of these changes and of the forces that have controlled them—both to understand the present pattern and predict its future evolution."

Though federal policies receive special attention, those of states and private agencies are covered also. An appendix summarizes federal policies relating to wildlife, soil, water, and mineral resources. One item of local interest in the wildlife section is reference to the earliest wildlife sanctuary in the United States, which was established in 1870 in what is now Oakland.

A second appendix consists of "A Chronological Summary of Important Events in the Development of Colonial and Federal Policies Relating to Natural Resources."

The book is designed for reference use and as a text. Surprisingly enough, it affords relatively easy reading, possibly because of the occasional use by Dr. Dana of colloquialisms, rather than the usual unrelieved sterile verbiage common to textbooks.

The volume will be of value to any natural resource worker involved with policy matters and should be of interest to others.—*Fred L. Jones, California Department of Fish and Game.*

The Singing Wilderness

By Sigurd F. Olson; Alfred A. Knopf, New York, 1956; 245 p., illustrated by Francis Lee Jaques. $4.

"The Singing Wilderness" is reminiscent of Aldo Leopold's "Sand County Almanac".

In both volumes the appeal of wilderness experience is clearly expressed with feeling and insight.

Mr. Olson is a well-known conservationist and is active in several national organizations dedicated to wilderness preservation. This book has stemmed from 30 years of enjoyment in the forest and lake wilderness of the Quetico-Superior country of northern Minnesota and adjoining Canada.

A collection of 33 essays is presented according to the four seasons—spring, summer, autumn, and winter. Each of the essays is headed by one of Francis Lee Jaques' fine pen and ink sketches.

One essay describes a stirring moonlight serenade by wild-flying loons. Another delicately shares a revel in wilderness silence. A collection of thoughts concerning the incomparable aroma and superior pyrotechnics of well-seasoned pine knots is gathered together. The final essay transmits to the reader the enjoyment and thrills of a once-in-a-lifetime midwinter encounter with timber wolves.

Throughout the book, Mr. Olson exhibits a rare ability to transpose esthetics into communicable terms. It is a pleasure to share his experiences in such a medium.

The book is not for the reference shelf. It is, rather, something to be read and enjoyed. The passages in it will stimulate successive selected rereadings, for all of the nuances of thought cannot be conquered in the first perusal.

"The Singing Wilderness" will be enjoyed in one degree or another by anyone who has an affinity for the outdoors.—*Fred L. Jones, California Department of Fish and Game.*

Experimental Design

By Walter T. Federer; The Macmillan Company, New York, 1955; xix + 544 + 47 p. $11.

This book brings together material hitherto available only from widely scattered sources and then certainly not as well presented as it is here. It is not an introductory text, but rather a technique handbook for advanced students. A detailed knowledge of basic statistical concepts is necessary for its effective use.

The introductory section has a brief but clear discussion of the principles of scientific experimentation, essentially based on the statistical approach. Chapter 2 discusses statistical tools and concepts as a preliminary exposure and exercise for the rest of the book. The bulk of the book thoroughly covers various types of experimental designs with their application, advantages, and disadvantages comprehensively discussed. In general, the conception and analysis of each design is presented first in the chapter and is followed by a discussion of the design's variation, with material on components of variance presented last. A bibliography of 340 citations is included.

This reviewer believes this book should be available to every serious researcher, either on his own shelf or in a library.—*J. Bruce Kimsey, California Department of Fish and Game.*

Laboratory Manual of Mammalogy

By E. Lendell Cockrum; Burgess Publishing Company, Minneapolis, 1955; iii + 160 p., illus. $4.

This spirally-bound manual was developed as an aid to students of mammalogy. While it emphasizes study of the mammals of Arizona, it is general in scope and thus generally applicable. Its particular benefit to wildlife management personnel is that it provides easy reference to subjects varying from skeletal characters and methods of taking standard specimen measurements to a key to the families and genera of North American mammals north of Mexico. Most of the chapters terminate with good lists of references to detailed studies of specific subjects. Of particular interest is Appendix B, which is a selected bibliography of area works on mammals. It lists the major contributions to mammalian literature for Alaska and the individual provinces of Canada, and for 43 of the United States.

It must be borne in mind that this publication is intended to guide the student toward further endeavors. The treatment is necessarily general, but the way is left open to attain the specific. *Henry A. Hjersman, California Department of Fish and Game.*

Travels and Traditions of Waterfowl

By H. Albert Hochbaum; The University of Minnesota Press, Minneapolis, 1955; xii + 301 p., illus. $5.

My praise for H. Albert Hochbaum and the results of his work as director of the Delta Waterfowl Research Station in Manitoba, Canada, is almost unlimited. I believe Mr. Hochbaum is a true example of the right man in the right place at the right time. For 16 years he has resided at the Delta station, studying the waterfowl of that area and along the south shore of Lake Manitoba. The station is sponsored by the North American Wildlife Foundation and the Wildlife Management Institute, and apparently operates in an atmosphere of complete academic freedom.

Being a waterfowl manager myself, and familiar with the author's earlier book *The Canvasback on a Prairie Marsh*, I was most excited when I learned of his new work. *Travels and Traditions of Waterfowl* is an example of keen observation allied with broad thinking, reported in a practical manner easily understandable by all.

The scientific value of the book comes from his analysis of one of the most dramatic mysteries of nature, that of bird migration. Mr. Hochbaum has seen that the blanket term "instinct" as the explanation for migration is in truth no explanation at all. He makes no pretense of omniscience—lays no claim to knowledge of the migration of other species. He does present impressive evidence that what he calls "tradition" plays an important, perhaps a major, part in the travels of waterfowl from their nesting grounds to their winter quarters and return.

The migration of birds has and always will intrigue the mind of man. How do birds make their long trips each year without being equipped with sextants and compasses, mathematical tables, or the gift of speech? I believe you will agree with the author's intrepretation that "tradition" is well founded and substantiated by recent band return information. Emphatically, this is a book for the layman as well as the scientist.

The book is divided into three parts. Part one is entitled *Travels of Waterfowl*, with chapters on (1) Patterns of local movement, (2) Learned response to the environment, (3) The visual world, (4) The function of memory, (5) The aerial environment, and (6) Awareness of time and space.

Part two is entitled *Migrations of Waterfowl*, with chapters on (1) The cycle of migration, (2) Flight trails south, (3) Homeward migration, (4) The classification of waterfowl travel, (5) The dimensions of travel, (6) The influence of bad weather, (7) Overseas migration, (8) Magnetic and radio fields, and (9) Awareness of direction.

Part three presents the *Traditions of Waterfowl*, with chapters on (1) Biological traditions, (2) Building new traditions, (3) Tradition and racial isolation, and (4) Broken traditions.

A 21-page bibliography covering the various aspects of travels, migrations, and traditions of waterfowl further attests to the thoroughness of Mr. Hochbaum's work.

To close without a reference to the excellent illustrations which accompany the text would be an injustice to the author. He is as capable an artist as he is an observer and writer.

In brief, *Travels and Traditions of Waterfowl* is a great book and an excellent contribution toward the understanding of waterfowl migrations and ecology.—*John B. Cowan, California Department of Fish and Game.*

Handbook of Tropical Aquarium Fishes

By Herbert R. Axelrod and Leonard F. Schultz; McGraw-Hill Book Company, Inc., New York, 1955; xii + 718 p., over 600 illustrations, incl. 180 in full color. $10.

Perhaps this contribution to the lore of tropical aquarium fishes has used the term "handbook" to mean a German "handbuch," which many think of as a work requiring at least two hands to pick up! Between its adequate cloth-bound covers are some 730 pages exhibiting a nice job of printing on a good quality of paper.

The first four sections take up 150 pages and consider Ichthyology, The Aquarium and Its Management, Plants in the Home Aquarium, and Diseases of Fish and Their Cure. The major portion of the book, over 500 pages, is devoted to the Catalogue of Fishes. In addition, there is a glossary which contains most, but not all, of the technical terms used in the book.

This book seems to be directed toward the advanced aquarist as well as the student of ichthyology. The aquarist will find the chapter on Ichthyology of special interest, as it deals with the history of ichthyology, methods of collecting fishes, preservation of fishes for identification purposes, distribution of fishes, and anatomy and functions. The second chapter, The Aquarium and Its Management, is a hodgepodge of information varying from such statements as "Water is composed of the two elements hydrogen and oxygen chemically bonded together" to the mathematical expression of pH $\left(\text{pH} = \frac{1}{\log_{10} \text{H-ion concentration in gram equivalents per liter}}\right)$. In addition, there appear techniques of importance only to persons interested in obtaining brine shrimp eggs as a commercial enterprise. The section on water in this chapter can not only lead to confusion, but may result in the reader's being left with 300 gallons of salt water on his hands.

The short chapter on Plants in the Home Aquarium seems adequately written and contains some excellent photographs. The chapter on Diseases of Fishes and Their Cure will please the aquarist. It describes diseases of the skin, eyes, and internal organs caused by worms, protozoa, bacteria, and fungi, and also provides recommendations for their treatment.

The Catalogue of Fishes is done in a scientific manner. It includes illustrations of the species, scientific name, range, size, temperament, temperature requirements, sex differences, and fin ray counts. In addition, for each species there are usually three or four paragraphs concerning coloration, feeding habits, and breeding habits. The illustrations in this portion of the book consists of photographs, both color and black-and-white, and drawings. The photographs for the most part are excellent. The drawings, however, are not so uniform in quality as the photographs, although some are outstanding. Some four hundred odd species are described in the Catalogue. Many of these, however, are not to be found in the neighborhood pet store, and have actually only been seen by collectors and scientists.

As with most first editions, there are the usual errors which will require corrections in subsequent editions. This book will be useful and worthwhile to most persons interested in tropical fishes.—*Harold Wolf, California Department of Fish and Game.*

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